Accelerometer Quantification of Physical Activity and Activity Patterns in Patients with Ankylosing Spondylitis and Population Controls

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ABSTRACT. ***Objective.*** To compare the total amount of physical activity (TPA) and time spent in various activity intensities of patients with ankylosing spondylitis (AS) and population controls, and to explore factors related to physical activity (PA).

Methods. Subjects were asked to wear a triaxial accelerometer for 7 days and to complete a series of questionnaires. Multivariable regressions were used to assess generic determinants of TPA in patients and controls, and in patients to explore demographic and disease-specific determinants of various PA intensities.

Results. One hundred and thirty-five patients [51 ± 13 yrs, 60% men, body mass index (BMI) 26.0 ± 4.3 kg/m^2] and 99 controls (45 ± 12 yrs, 67% men, BMI 25.1 ± 4.3 kg/m^2) were included. Patients did not differ from controls regarding TPA (589 vs 608 vector count/min, p = 0.98), minutes/day spent in sedentary (524 vs 541, p = 0.17), and light PA (290 vs 290 p = 0.95), but spent fewer minutes/day in moderate to vigorous PA (MVPA; 23 vs 30 min/day, p = 0.006). Perceived functional ability (physical component summary of the Medical Outcomes Study Short Form-36) and BMI were associated with TPA independent of having AS (p interaction = 0.21 and 0.94, respectively). Additional analyses in patients showed that time spent in MVPA was negatively influenced by BMI, physical function (Bath AS Functional Index), and disease duration. In patients ≥ 52 years old, a higher Bath AS Disease Activity Index was associated with less time spent in sedentary and more time spent in light activities.

Conclusion. Compared with controls, patients with AS had similar TPA, but may avoid engagement in higher intensities of PA. Lower levels of functional ability and higher BMI were associated with lower TPA in both patients and controls. (First Release November 1 2015; J Rheumatol 2015; 42:2369–75; doi:10.3899/jrheum.150015)

Key Indexing Terms:
PHYSICAL ACTIVITY — ANKYLOSING SPONDYLITIS — ACCELEROMETER
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Regular physical activity (PA) has well-known beneficial health effects. Moderate and vigorous intensities of PA (MVPA) are especially considered vital to enhance health[1,2]. Research in the overall population has shown clear positive effects of MVPA on health. A recent population study in 217,755 middle-aged adults indicated that time spent in

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vigorous intensity of PA, independent of the total amount of PA, was associated with a reduced risk of mortality[3]. Patients with ankylosing spondylitis (AS) can be hampered in their daily habitual activities because of pain, stiffness, and limitations in mobility[4,5]. It might therefore not be straightforward for patients to engage in sufficient PA to maintain or improve health. In AS, the literature on the total amount of physical activity (TPA), representing all measured movement of the body produced by skeletal muscle[6], as well as time spent in different intensities of movement, is scarce and contrasting. When using an objective measure to assess PA, evidence of 2 studies examining a small group of patients with AS[7] or axial spondyloarthritis (axSpA)[8] shows that patients have a similar or slightly lower level of TPA than healthy controls, respectively. Regarding time spent in different levels of intensity, patients with axSpA were shown to spend less time in MVPA in comparison with controls[8]. However, in a study based on a validated recall questionnaire to assess PA, it was reported that patients with SpA, including AS, more often than healthy controls met the recommendations of the World Health Organization (WHO)[9], i.e., 150 min of PA a week in moderate intensity, 60–75 min in vigorous intensity, or an equivalent combination of both[2,10]. Additional data are needed to elucidate these contradicting findings and to see whether findings such as meeting the WHO recommendations remain once PA is objectively measured.

When aiming at optimizing PA in patients with AS, it is important to understand factors contributing to PA and to explore whether such factors would be different in patients compared with healthy individuals. This is relevant because it might reveal that patients require different approaches to optimize PA and no such data are available. Among patients, the limited cross-sectional evidence suggests that higher levels of PA are associated with lower disease activity and better spinal mobility, physical function, and health-related quality of life, as well as lower levels of C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR)[7,9,11,12,13]. On the other hand, data have been reported that heavy loading jobs can accelerate spinal radiographic damage[14]. A first step to elucidate these relevant issues is to explore PA and its patterns in patients with AS.

Therefore, given the previously mentioned gaps in knowledge, the primary aim of our current study was to compare TPA as well as time spent in different intensities of PA in patients with AS and population controls using validated accelerometers. Secondary aims were first to study whether known determinants of PA such as difficulties in functional ability and a higher body mass index (BMI) have a similar influence on the TPA in patients and controls, and next to investigate the association between disease-specific determinants and time spent in various intensities of PA in patients with AS. It was hypothesized that patients would not differ from controls regarding total performed PA, but would spend less time in MVPA.

MATERIALS AND METHODS

The Social Participation in AS Study (SPASS) was a multicenter cross-sectional study that first aimed to assess social role participation in an online questionnaire survey and second to investigate objectively assessed PA in patients with AS compared with population controls in a random subsample for whom an accelerometer was available. The study protocol was approved by the ethics committee of the academic hospital Maastricht and Maastricht University.

Patients. Patients of at least 18 years, registered with a diagnosis of AS in each of the 6 participating rheumatology departments and for whom the rheumatologist confirmed they fulfilled the modified New York criteria for AS, were invited by a letter. Patients were excluded if they had no access to the Internet or were not familiar with the Dutch language. Figure 1 illustrates that 246 of a total of 740 patients with AS (33%) consented to participate in the SPASS study. Of a random sample, 154 also participated in our current substudy on PA. All patients provided written informed consent.

Controls. Control subjects were recruited from a national open online panel of the research institute Ipsos (Amsterdam, the Netherlands). Based upon our expectations of a cross-sectional sample in AS, the population controls were sampled to have an average age of 42 years and a male:female distribution of 3:1[15]. Subjects were excluded if they had any musculoskeletal disorders or if they were not familiar with the Dutch language[16]. Figure 1 shows that of the 510 of a total of 2767 controls (18%) who participated in the online questionnaire survey, a randomly selected subgroup (n = 109) agreed to wear the triaxial accelerometer.

Assessments. PA was measured using a triaxial accelerometer (Actigraph GT3X, Actigraph LLC Pensacola), which had shown good validity when using energy expenditure measured by doubly labeled water as the gold standard[17]. It was attached at the lower back of the subject by means of an elastic belt and measured minute by minute accelerations (expressed as counts) in the anteroposterior, mediolateral, and longitudinal axes of the trunk. Subjects received the accelerometer by mail and were instructed to wear the device for 7 consecutive days during waking hours, except during water activities. Data were considered to be complete if subjects wore the accelerometer for at least 3 days and 10 h per day. In addition, whenever the device measured consecutive zeroes over a period of ≥ 60 min, this was classified as a non-wear period. From the output of the 3 axes, the vector magnitude counts (VM^3) could be calculated [$VM^3 = \sqrt{(\text{total counts axis } 1^2 + \text{total counts axis } 2^2 + \text{total counts axis } 3^2)}$], and subsequently counts per day (CPD = VM^3 ÷ total wear time in calendar days) and counts per minute (CPM = VM^3 ÷ total wear time in minutes). For categorizing accelerometer data into different intensities of PA, Troiano cutoff values were used to calculate the number of minutes spent in sedentary (0–99 CPM), light (100–2019 CPM), moderate (2020–5998 CPM), or vigorous PA (≥ 5999 CPM)[18]. As a result, average minutes spent per day in each intensity could be calculated as follows: total minutes (intensity) ÷ total wear time in calendar days. Using the average minutes spent in MVPA per day, subjects who met the WHO recommendations could be identified.

Questionnaire and measures. Questions on socioeconomic background and lifestyle consisted of information about sex, age, and highest finished educational degree, as well as weight and height. To assess generic health, the Medical Outcomes Study Short Form-36 (SF-36) was included. The SF-36 assesses difficulties attributable to mental or physical health across 8 domains: social function, physical function, bodily pain, role physical, role emotional, general health, vitality, and mental health. From the domains, 2 summary scores can be calculated: the physical component summary (PCS) and the mental component summary (MCS), ranging from 0 to 100 (higher scores reflecting better health)[19,20].

To assess aspects of AS-related health, patients indicated their diagnosis duration (time since diagnosis, in yrs) and completed the Bath AS Disease Activity Index (BASDAI) and the Bath AS Functional Index (BASFI)[21,22]. Finally, information about the current use of medication, i.e., use of tumor necrosis factor-α blocking therapy, was obtained.

Statistics. All analyses were performed with PASW Statistics 20 (SPSS).

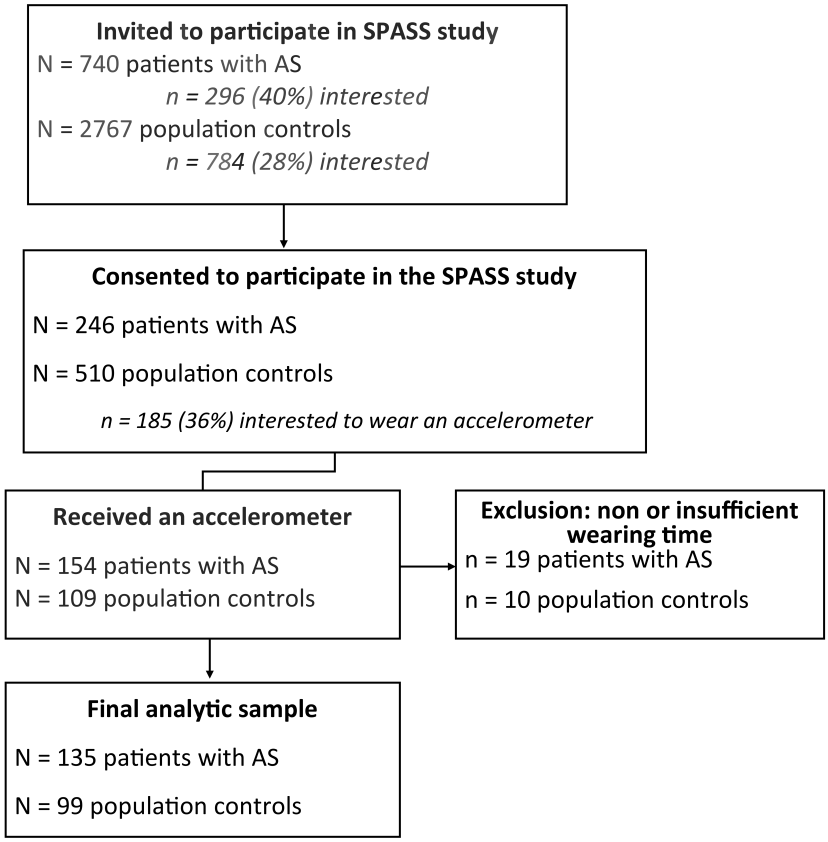

Figure 1. Subjects flowchart. AS: ankylosing spondylitis; SPASS: Social Participation in AS Study.

After checking normality of the data, comparisons between patients and controls were performed with independent Student t tests or Kruskal-Wallis test (SF-36 PCS, MCS, calendar days the accelerometer was worn, and time active in MVPA). To adjust the comparisons of the different accelerometer outputs between patients and controls for multiple comparisons, the Benjamini-Hochberg procedure was performed using a false discovery rate of 20%[23]. Given the relatively low amount of time spent in vigorous PA, these minutes were combined with the time spent in moderate PA for further analyses. When exploring the differences between patients and controls in TPA (CPM) or the time spent in various intensities of PA, linear regressions were used to adjust for possible differences in age, sex, and BMI between both groups.

Multivariable regression was also used in an explanatory model to assess whether the effect of generic functional abilities (SF-36 PCS) and BMI on TPA was independent of age, sex, and having a diagnosis of AS. Linearity was checked as well as possible interactions of groups with BMI, PCS, age, and sex.

Finally, to understand the influence of disease-related variables on minutes spent in sedentary, light, and (square root transformed) MVPA in patients with AS, multivariable regression analysis was performed with age, sex, BMI, diagnosis duration, BASDAI, and BASFI as potential determinants. Because minutes spent in MVPA were slightly skewed, the variable was square root transformed. P values ≤ 0.05 were considered statistically significant.

RESULTS

Samples. The final sample consisted of 135 patients with AS and 99 population controls (Figure 1). The characteristics of both patients and controls are presented in Table 1. Patients were older and had a worse self-reported physical health (SF-36) in comparison with population controls.

PA at different intensities in patients with AS and population controls. The median (interquartile range) of the number of calendar days patients wore the accelerometer was 7 (6–7) days and for controls 7 (7–8) days. Patients with AS did not differ from controls regarding the TPA expressed in CPM (Table 2), not even after adjusting for age, sex, and BMI. Regarding the sum of time spent in all different intensities, which was also equivalent to the total wearing time in minutes, the population controls registered on average 25 min/day more activity than patients (p = 0.01). This difference could be attributed mainly to more time (17 min/day) in sedentary activity by controls, although this was not statistically significant. The time spent in light activities was the same in both groups. Patients spent 7 fewer minutes a day in MVPA (p = 0.006) compared with controls, which resulted in a lower percentage of patients meeting the norm of 150 min of at least moderate PA a week (46.7% vs 59.6% in controls, p = 0.05). In addition, the findings between groups remained significant after correcting for the false discovery rate and did not change after controlling for age, sex, and BMI.

Table 1. Demographic and health characteristics of the patients with AS and population controls. Values are mean (SD) [minimum–maximum] unless otherwise specified.

Characteristic	Patients with AS, n = 135	Controls, n = 99	p
Age, yrs	51 (13) [24–79]	45 (12) [23–84]	< 0.001
Males	81 (60)	66 (67)	0.34
Education, at least 12 yrs	118 (87)	86 (87)	0.90
Employed, n (%)	78 (58)	84 (85)	< 0.001
BMI, kg/m^2	26.0 (4.3) [17.0–41.8]	25.1 (4.3) [16.8–47.7]	0.09
Diagnosis duration, yrs	16.5 (12.1) [0–61]	—	—
BASDAI, 0–10	4.3 (2.2) [0–9.5]	—	—
BASFI, 0–10	4.1 (2.6) [0–10]	—	—
Biological medication, n (%)	69 (51)	—	—
SF-36 PCS, 0–100	38.8 (10.7) [9.9–61.9]	55.7 (6.0) [24.1–69.5]	< 0.001
SF-36 MCS, 0–100	50.2 (12.7) [10.9–70.5]	52.2 (8.7) [20.1–63.2]	0.99

AS: ankylosing spondylitis; BMI: body mass index; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BASFI: Bath Ankylosing Spondylitis Functional Index; SF-36: Medical Outcomes Study Short Form-36; PCS: physical component summary; MCS: mental component summary.

Table 2. Results of total PA and time spent in different intensities of PA as assessed by the 7-day accelerometer registration, separately for patients with AS and population controls. Values are mean (SD) [minimum–maximum] unless otherwise specified.

Variable	Patient with AS, n = 135	Controls, n = 99	p	p*
VM^3, counts/min	589 (202) [157–1158]	608 (219) [150–1465]	0.98	0.86
VM^3, counts/day	492,400 (173,511) [116,773–932,839]	521,847 (178,955) [126,538–1,025,867]	0.21	0.245
Time active, min/day	837 (77) [646–1058]	862 (68) [647–993]	0.01	0.04
Sedentary, min/day	524 (99) [279–783]	541 (94) [247–751]	0.17	0.238
Light intensity, min/day	290 (86) [40–520]	290 (74) [80–462]	0.95	0.86
Moderate intensity, min/day	22 (18) [0–122]	28 (20) [4–109]	0.02	0.05
Vigorous intensity, min/day, total n (%) = 30 (22)	1 (4) [0–22]	2 (5) [0–32]	< 0.001	0.01
At least 150 min of MVPA a week, n (%)	63 (46.7)	59 (59.6)	0.05	—

* P value is the Benjamini-Hochberg adjusted p value for multiple comparisons. AS: ankylosing spondylitis; PA: physical activity; VM^3: vector magnitude counts = $\sqrt{(\text{total counts axis } 1^2 + \text{total counts axis } 2^2 + \text{total counts axis } 3^2)}$; MVPA: moderate to vigorous PA.

Association between total PA and possible determinants in patients with AS and controls. In the multivariable analyses on TPA (CPM), the age, male sex, and group (having AS) were not significant contributors. Better self-reported functional ability was associated with more TPA (β 4.3, p = 0.005). For every point the PCS of the SF-36 increased, TPA increased 4.3 CPM. In addition, a higher BMI was associated with less TPA (β –7.9, p = 0.01), indicating that every point increase in the BMI was associated with a decrease in TPA of 7.9 CPM. There were no significant interactions between group and any of the other variables.

Determinants of various intensities of PA in patients with AS. In the multivariable models with minutes spent in sedentary PA and light PA as dependent variables, a significant interaction effect of age and BASDAI was found and consequently the regression models were stratified for age (at the median of 52 yrs). In patients aged under 52 years (n = 66, 56% men), a higher BMI was associated with more time per week spent in sedentary PA (β 8.6, p = 0.007; Table 3). In contrast, patients 52 years or older (n = 69, 64% men), being male (β 45.6, p = 0.04), and having a higher BMI (β 5.6, p = 0.02) were associated with more time spent in sedentary PA. In addition, the same analyses showed that a lower BASDAI was associated with less time spent in sedentary PA (β –20.7, p = 0.006). Regarding the analyses with time spent in light PA (Table 3), none of the entered explanatory variables were contributory in the group of patients of < 52 years. In the group of patients ≥ 52 years, a significant association with higher BASDAI and more time in light PA was found (β 14.61, p = 0.04). Of note, the sum of total time spent within all activity intensities did not differ between the strata of patients older and younger than 52 years (p = 0.80).

Finally, no interactions were observed when exploring the time spent in the square rooted MVPA. In the model (Table

Table 3. Results of the multivariable regressions investigating the association of several explanatory factors and minutes spent in sedentary, light, and MVPA per day in patients with ankylosing spondylitis.

Explanatory Factors	Age < 52 Yrs, n = 66 (56% men)				Age ≥ 52 Yrs, n = 69 (64% men)			
	β	SE	p	Partial R	β	SE	p	Partial R
Sedentary PA								
Constant	318.6	77.5	< 0.001	—	383.9	69.8	0.000	—
Male	–27.1	27.9	0.34	–0.13	45.6	22.1	0.04	0.25
BMI	8.6	3.0	0.007	0.35	5.6	2.4	0.02	0.28
Diagnosis duration, yrs	1.9	1.4	0.19	0.17	0.9	0.8	0.30	0.13
BASDAI, 0–10	–11.8	8.3	0.16	–0.18	–20.7	7.3	0.006	–0.34
BASFI, 0–10	6.9	6.8	0.32	0.13	8.8	6.2	0.16	0.18
		R = 0.45 (R^2 = 0.20)				R = 0.55 (R^2 = 0.31)		
Light PA								
Constant	389.8	70.4	< 0.001	—	374.9	68.0	< 0.001	—
Male	11.4	25.3	0.65	0.06	–5.6	21.5	0.79	–0.03
BMI	–2.3	2.8	0.40	–0.11	–4.1	2.4	0.09	–0.21
Diagnosis duration, yrs	–1.0	1.3	0.43	–0.11	–1.0	0.8	0.23	–0.15
BASDAI, 0–10	0.5	7.5	0.95	0.01	14.6	7.2	0.04	0.25
BASFI, 0–10	–9.4	6.2	0.14	–0.20	–4.9	6.0	0.42	–0.10
		R = 0.35 (R^2 = 0.12)				R = 0.386 (R^2 = 0.15)		
√MVPA, in patients across all age categories								
Constant	7.3	1.2	0.000	–				
Age	0.01	0.01	0.40	0.08				
Male	0.32	0.35	0.36	0.08				
BMI	–0.1	0.04	0.007	–0.24				
Diagnosis duration, yrs	–0.04	0.02	0.02	–0.21				
BASDAI, 0–10	0.1	0.11	0.30	0.09				
BASFI, 0–10	–0.2	0.09	0.03	–0.19				
		R = 0.43 (R^2 = 0.19)						

PA: physical activity; MVPA: moderate to vigorous PA; BMI: body mass index; BASDAI: Bath Ankylosing Spondylitis Disease Activity Index; BASFI: Bath Ankylosing Spondylitis Functional Index.

3), negative associations with higher BMI (β –0.01, p = 0.007), longer diagnosis duration (β –0.04, p = 0.02), and higher BASFI (β –0.2, p = 0.03) were observed.

DISCUSSION

The findings of our study confirmed our hypothesis that patients with AS did not differ from population controls in the total amount of objectively measured PA, but spent less time in MVPA. Further explorations revealed that the negative influence of impaired functional ability and BMI on TPA was similar in patients as in controls. Among patients, increased BMI, diagnosis duration, and BASFI, but not reported disease activity, reduced the time spent in MVPA. Remarkably, in older patients, a higher disease activity was associated with less time spent in sedentary but more time spent in light intensities of PA.

When interpreting the current findings from the perspective of existing literature, it should be noted that different assessment tools are used, and in comparison with objective accelerometers, retrospective self-reports are hampered by the possible overestimation of PA because of recall bias[24].

Our findings on TPA assessed with an accelerometer are in agreement with Plasqui, *et al*, who also found no differences in a much smaller group of 48 patients with AS and controls[13]. In contrast, a study by Swinnen, *et al* (n = 80) concluded that, in total, activity of patients with axSpA was lower compared with controls. However, in that study, both patients [median PA level (PAL) of 1.45] and controls (median PAL of 1.54) had a remarkably low PAL in comparison with reference values found in the general population (mean PAL ~1.7), indicating that care should be taken when interpreting these results[8,25]. For referencing, the study by Plasqui, *et al* found a mean PAL of 1.73 in patients with AS and 1.74 in controls, results in line with reference values as measured in the general population[13].

As for time spent in different intensities of PA, patients in our study spent less time in more vigorous intensities of PA, which was in line with the additional results of the study by Swinnen, *et al*[8]. When considering the proportion of patients complying to the current WHO recommendations as assessed by a validated recall questionnaire, Haglund, *et al*[9] reported that 68% of 2126 patients with SpA complied with these recommendations (reflecting at least moderate PA)[2], which was slightly better than the proportion reported from the general population[9]. Using an accelerometer, we found that only 47% of the patients and 60% of the directly compared controls reached this level. Validated recall questionnaires are regarded as more practical for clinical use, yet the selection of commercially available accelerometers and activity monitors is rapidly increasing[26], which might provide opportunities for a more extensive use of these devices in future research.

Regarding factors contributing to the TPA in patients and controls, the negative effect of BMI was apparently not amplified in patients. In the general population, it is known that overweight (BMI ≥ 25 kg/m^2) is associated with lower PA[27]. Moreover, in AS it was shown that overweight relates to poorer perceptions about the benefits of exercise and provides a greater awareness of the barriers to exercise[28]. Overweight and/or perceptions of overweight may hamper PA engagement[29,30], and seemingly this effect is the same in controls as in patients. Among similar lines, no group differences were observed with regard to functional ability measured by the SF-36 PCS, which was associated with less TPA. Although the interaction between the group variable with SF-36 PCS was not significant, the SF-36 PCS in the control group was distributed in a clustered pattern (i.e., controls did not experience functional problems), whereas a broader distribution over the range of functional ability was observed in patients. For this reason, the absence of a significant group effect should be interpreted with some caution.

Within patients, BMI, limitations in physical function (BASFI), and an increasing diagnosis duration were associated with reduced MVPA. The reduced time in MVPA within patients was previously confirmed by Prince, *et al*, who interviewed 52 patients with AS and confirmed that patients reported a decline in both time and intensity in sports and recreational PA participation after diagnosis[31]. The independent influence of diagnosis duration might be relevant to accumulate radiographic damage in AS and likely independently affects physical function and thus engagement in PA[5,32]. However, the BASDAI was not independently relevant for time spent in MVPA. We found that in older patients, but not younger patients, an increase in the BASDAI was significantly associated with less time spent in sedentary PA and also with more time spent in light intensity PA. The availability of more leisure time to be physically active is not a likely explanation because in both age groups, a similar number of patients had paid work. Apparently, older patients have experienced more than younger patients that light intensities of PA, such as walking and mild stretching, have beneficial effects on their functioning and well-being, despite somewhat more pain and stiffness[33]. Contrasting results can be found in a questionnaire study in which 78 patients with AS with a higher disease activity (mean age 51.4 yrs) reported a lower amount of TPA and spent less time in walking and vigorous intensity activities than patients with a lower disease activity (mean age 46.9 yrs)[12]. In our study, patients with a BASDAI ≥ 4 did not differ regarding the total PA or intensities of PA compared with patients with a BASDAI < 4.

Regular exercise is proposed by the Assessment of SpondyloArthritis international Society and European League Against Rheumatism recommendations as part of the nonpharmacological treatment of AS[34]. Activities of a higher intensity as some forms of exercise have known beneficial health effects, including cardiovascular risk factors[35]. Since our results revealed that patients spent less time in more vigorous intensities of PA than controls, more emphasis should be given to exercise programs that do not concentrate only on stretching and postural correction, but also on higher intensities of PA, especially because novel evidence in another study indicated that in healthy middle-aged adults, PA of vigorous intensity was related to declined risk of mortality[3]. While we call for more engagement in MVPA in patients with AS, we also need to admit that more research is needed on whether such activity would be beneficial for all patients in all stages of their disease. Another recent study found that in patients who were blue-collar workers, a surrogate for more PA, radiographic progression of spinal damage was significantly higher compared with white-collar workers[14]. However, it is unclear whether this depended on the type of vigorous physical activities; the type of overall health benefits is also uncertain. Yet differences in radiographic progression were small and likely positive effects of PA will outweigh these small differences, but more research is needed on this aspect.

Some limitations need to be addressed. Because of the cross-sectional design of our study, statements about causality of relationships cannot be drawn.

Further, we did not examine inflammation markers such as CRP and ESR, and therefore were unable to investigate the role of objective disease activity on the PA of patients. While the inclusion of the control group was a strong point of our study, we were not able to fully match the control population to the age and sex of the AS group, but none of these variables contributed to the measured PA outcomes and were controlled for in all further analyses. Moreover, the recruitment of both patients and controls to wear an accelerometer was voluntary, which could have led to selection bias based on motivation to wear an accelerometer. However, this applied to both patients and controls so that any bias likely affected both groups, preserving internal validity.

Patients with AS performed the same TPA as population controls, but spent less time in MVPA. Higher BMI, impaired physical function, and a longer diagnosis duration are the main factors hampering engagements in MVPA in patients having AS.

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