THERAPEUTIC ADVANCES in
Musculoskeletal Disease

Original Research

Impact of daily physical therapy over 2 weeks on spinal mobility including objective electronic measurements and function in patients with axial spondyloarthritis

Ther Adv Musculoskelet Dis

2024, Vol. 16: 1–13

DOI: 10.1177/1759720X231224212

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Abstract

Background: Patients with axial spondyloarthritis (axSpA) are often compromised by impaired function and mobility. The standardized 2-week inpatient program 'multimodal rheumatologic complex treatment' (MRCT) was designed for patients with axSpA. The Epionics SPINE (ES) is an objective tool validated to assess mobility.

Objective: To investigate the impact of MRCT on physical function and mobility including range of motion (RoM) and kinematics (RoK).

Design: Single-center interventional, observational trial.

Methods: Patients with axSpA presenting with high disease activity and impaired physical function were consecutively recruited to undergo MRCT. Assessments performed before (V1) and after (V2) the intervention included Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), Bath Ankylosing Spondylitis functional index (BASFI), Bath Ankylosing Spondylitis Metrology Index (BASMI), the ankylosing spondylitis physical performance index (ASPI), the Short Physical Performance Battery (SPPB), and ES measurements.

Results: At baseline, the 80 patients included had: BASDAI 5.5 ± 1.5, BASFI 5.6 ± 2.0, BASMI 4.2 ± 1.8, SPPB 13.8 ± 1.8, and ASPI 37.3 ± 18.1 s. Clinically relevant improvements between V1 *versus* V2 were noted for BASFI, BASMI, and all other assessments ($p < 0.001$), and also for ES measures of RoK (all $p < 0.003$) and RoM (all $p < 0.04$), while a positive trend was seen for flexion and extension (RoM). There was no significant effect of changes in medication (all $p > 0.05$).

Conclusion: The 2-weeks MRCT was associated with definite improvements of function and mobility. Importantly, the effect of this extensive physical activity was confirmed by using the ES as an objective tool to assess spinal mobility. The ES demonstrated for the first time that the RoK of spinal mobility can significantly improve related to an exercise intervention.

Trial registration: Ethical Committee: Ruhr-Universität (reference-number: 19-6735-BR).

Keywords: axial spondyloarthritis, outcome measurements, physical activity, physical therapy, spine

Received: 22 June 2023; revised manuscript accepted: 11 December 2023.

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Introduction

Axial spondyloarthritis (axSpA) is a chronic rheumatic disease that is characterized by inflammation and structural changes in the axial skeleton, including the sacroiliac joints (SIJs) and the spine.[1,2] One major clinical symptom is inflammatory back

pain.[3] Depending on the presence or absence of definite radiographic changes in the SIJs, patients with axSpA may be differentially classified into non-radiographic axSpA (nr-axSpA) or radiographic axSpA (r-axSpA), the latter being equivalent to the classical ankylosing spondylitis (AS).[4–7] There are two pathognomonic pathophysiological features of the disease: axial inflammation and new bone formation which may both cause pain, impaired function, and reduced spinal mobility.[8–10] AxSpA usually starts in early adulthood and therefore patients are affected in their professional and daily activities already early but basically for their whole life.[2]

Besides pharmacological treatments, non-pharmacological therapies such as physiotherapy being important for many patients are part of international and national recommendations and regular physical activity (PA) should be an integral part of standard care throughout the course of disease.[11–13] There is evidence that regular PA is beneficial for the management of patients with axSpA.[14–17] Recent Assessment of Spondyloarthritis international Society (ASAS)-European League Against Rheumatism (EULAR) recommendations for the management of axSpA emphasize the importance of PA, exercise, and lifestyle changes such as smoking cessation.[11] Furthermore, the EULAR recommendations for PA in people with inflammatory arthritis and osteoarthritis were published in different languages to provide evidence-based recommendations on the performance and implementation of PA for patients. This also contains helpful definitions and proposals on various aspects of PA in terms of frequency, intensity, and movement patterns.[14,18] PA is defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure above resting (basal) levels and includes the four domains of cardiorespiratory fitness, muscle strength, flexibility, and neuromotor performance.[14,19] PA broadly encompassing exercise, sports, and physical activities done as part of daily living, occupation, leisure, and active transportation can be performed individually, in groups, supervised or non-supervised and should always include behavioral change techniques (BCT) to promote long-term adherence.[19–22]

As shown recently, PA may reduce disease activity and improve spinal mobility, function, and quality of life in patients with axSpA.[16,23] However, patients with axSpA are in general less active and have a decreased spinal mobility compared with healthy controls.[24–26] Function is mainly assessed by the patient-reported Bath AS functional index (BASFI) while spinal mobility is widely assessed by the Bath AS Metrology Index (BASMI).[27,28] However, self-reported physical function may not necessarily indicate the true physical performance level of a patient. That is why performance-based tests are increasingly used to objectively assess physical performance. The short performance battery test (SPPB), a geriatric test,[29] was recently shown to be impaired in many patients with axSpA.[30] The disease-specific AS Performance-based Index (ASPI) which is based on three BASFI items measures time, pain, and exertion to perform daily activities.[31,32] The Epionics SPINE (ES) is an electronic device capable of objective measurement for spinal mobility and recently validated for patients with axSpA.[28,31–34]

A standardized 2-week multimodal inpatient program named multimodal rheumatologic complex treatment (MRCT) which has been especially designed for inpatients with axSpA includes supervised individual and group sessions of physiotherapy, occupational therapy, and cognitive behavioral therapy. Furthermore, electrotherapy such as transcutaneous electrical nerve stimulation-therapy and thermotherapy such as mud packs and heat lamps as well as finger/hand exercises in warm or cool sand or rapeseed are performed in selected patients guided by physiotherapists and occupational therapists.

The program combines all four domains of PA described above. Patients are required to perform at least 11 h of training sessions per week, but they are encouraged to extend this by using the hospital's gym and by individual training sessions repeating the exercises previously learned in supervised sessions.

MRCT is a special program designed by rheumatological acute care clinics in Germany to offer patients who have functional deficits due to pain and/or inflammation a predefined comprehensive and intensive range of non-pharmacological therapies within a predefined time period. Thus, this program is only financed by the payers, which, in Germany, means the insurance companies, if patients complete the predefined program within the full period of 2 weeks. This ensures that hospitals offer the appropriate number and selection of therapies. Furthermore, patients are motivated to participate.

In this study we investigated the impact of daily physical therapy over 2 weeks – as part of the predefined program described above – on clinical outcomes including disease activity, function, mobility, and objective electronic spinal mobility measurements of range of motion (RoM) and range of kinematic (RoK) with the ES which was used in prior trials on mechanical back pain as well as axSpA patients.[34–38] The device provides objective information on spinal RoM and speed of motion assessed as RoK in all planes. ES scores correlate with BASMI results and have been shown to convincingly differentiate between patients with axSpA and healthy controls and also between patients with r- or nr-axSpA.[34] Furthermore, in patients with r-axSpA *versus* those with nr-axSpA, not only was mobility more limited but also tasks were performed more slowly.[34] RoM and RoK are directly related to radiographic changes in the axial skeleton of patients with axSpA.[39]

In addition, in this setting, the ES measurements were tested for their sensitivity to change.

Methods

This single center study was designed as an interventional, observational trial without randomization and without control group. The patient recruitment period took place from January 2020 to December 2021. Consecutive in-patients ⩾18 years diagnosed with axSpA by a rheumatologist were prospectively included if presenting with impaired physical function as defined by a BASFI score >2. Patients over 70 years and those who had undergone spinal surgery and pregnant women were excluded. All patients recruited underwent a standardized MRCT especially designed for patients with axSpA.

The MRCT designed for inpatients with axSpA lasts at least 14 days and includes the use of at least three areas of therapy: (1) physiotherapy individually and in groups, (2) occupational therapy, and (3) cognitive behavioral therapy in different combinations. The program also includes daily gymnastics (45 min) and water exercises (30 min), individual physiotherapy, muscle strength, thermotherapy, electrotherapy (30 min each 2–3 × week), and at least three group therapies including muscle strengthening, walking, gymnastics, or qigong, lasting 30 min each. Furthermore, patients were encouraged to additionally perform daily supervised training session and individual exercises to increase cardiovascular fitness and muscle strength (Figure 1).

Baseline visit V1 was performed directly before and visit V2 right at the end of the MRCT intervention. Both visits were performed in the morning time of the day (Figure 1).

For analyses patients were divided based on the classification into r-axSpA or nr-axSpA according to the absence or presence of definite structural changes in the SIJ as assessed by conventional radiography and scored as explained in the modified New York criteria.[5]

Clinical assessments

At V1 baseline data including demographic and clinical data such as age, sex, body mass index (BMI), Human Leukocyte Antigen (HLA)-B27, and C-reactive-protein (CRP) were measured. Drug therapy was categorically collected [no therapy, non-steroidal anti-inflammatory drug (NSAID), biological diesease-modifying anti-rheumatoc drug (bDMARD) at V1 and changes in medication during the 14 days were collected at V2.

Disease activity was assessed by the Ankylosing Spondylitis Disease Activity Score [AS Disease Activity Score (ASDAS), only V1] and Bath Ankylosing Spondylitis Disease Activity Index (BASDAI),[40,41] physical function by BASFI,[27] global functioning, and health by the ASAS Health Index (ASAS HI).[42,43]

Different measurements of mobility were performed. Besides the BASMI[28] also performance-based tests, the ASPI[32] and the SPPB[29] as well as objective electronic measurements of spinal mobility with the ES were assessed.

Measurements with the ES were performed based on a choreography of predefined exercises to record spinal mobility including flexion, extension, rotation, and lateral flexion of the spine. As described earlier in more detail,[34] the ES uses strain gauge sensors attached in predefined positions at the back, to provide a sensitive measure of electrical resistance, and thus of the aperture angles, according to the curvature in each of six 50-mm sensor segments. The ES is therefore capable to assess RoM, measured and calculated in angular degrees and the maximum speed with which the exercises have been performed (RoK), measured in angular degrees/second.[34,36,38,44,45]

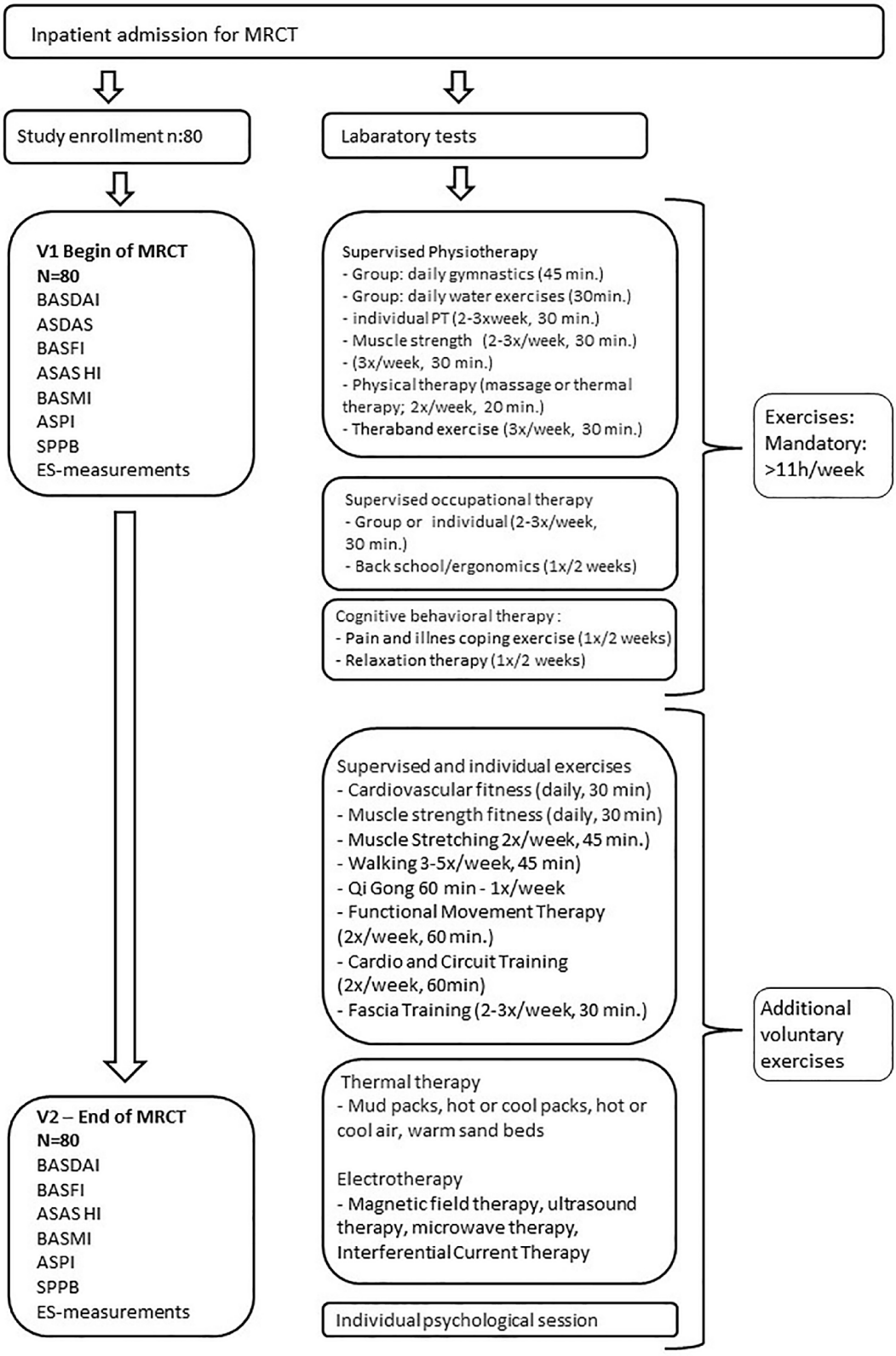

Figure 1. Study design and overview of MRCT.
ASAS HI, Spondyloarthritis international Society Health Index; ASDAS, AS Disease Activity Score; ASPI, Ankylosing Spondylitis Performance-based Improvement; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; BASMI, Bath Ankylosing Spondylitis Metrology Index; min., minutes; MRCT, multimodal rheumatologic complex treatment; PT, physiotherapy; V, visit.

RoK represents the velocity of spinal mobility. Our study was also designed to prove that assessments with the ES are sensitive to change.

Statistical analysis

All explorative statistical analyses were performed using the software SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Data were intentionally calculated to a full significance level of 5%. They were not corrected for multiple testing. p Values ≤ 0.05 were considered significant. Patient demographics, clinical assessments, and ES variables at baseline were compared using unpaired t tests. Clinical assessments and ES variables before and after MRCT were compared by paired t tests. For the independent and paired samples T test, Cohen's d was used to calculate the effect size. Normal distribution was evaluated beforehand using Shapiro–Wilk test and was present in some but not all variables. Due to the large sample size, t tests were performed because of their greater statistical power. Extreme outliers were excluded, moderate outliers were kept in the analyses. Additionally, Wilcoxon test was performed for clinical assessments and ES before and after MRCT. Missing data in one or more variables were kept in the analyses but excluded for that variable, leading to different sample sizes for different variables. For comparison of more than two groups analysis of variance and Tukey or Games–Howell *post hoc* analysis was performed.

Results

Of a total of 80 patients enrolled, all patients were included in the analyses: 53 with r-axSpA (66.3%) and 27 with nr-axSpA (33.7%). Participants were mostly male ($n=59$; 73.8%), mean age 46.6 ± 11.3 years, mean BMI 28.2 ± 5.3 kg/m^2, and a mean CRP of 11.0 ± 22.9 mg/L (<5 mg/L is considered as normal) (Table 1). Most patients ($n=59$) (73.8%) were HLA-B27 positive (two missing values). Their mean disease duration was 10.7 ± 9.8 years and the mean duration of symptoms was 18.8 ± 11.3 years (Table 1).

Disease activity as assessed by ASDAS was 3.2 ± 0.9 and 5.5 ± 1.5 by BASDAI, both indicating high disease activity. Patients had a moderate impairment of global functioning with a mean ASAS HI of 8.7 ± 3.2. Limitations in physical function (BASFI 5.6 ± 2.0) and impairments in spinal mobility (BASMI 4.2 ± 1.8) were documented.

All ASPI items were performed by no more than 55 patients (69%), while 25 were unable to perform the tasks due to impairment of function.

The results of the performance-based tests showed a mean ASPI of 37.3 ± 18.1 s while the mean SPPB score was 10.1 ± 1.5. Only 11 patients (13.8%) had an SPPB score ≤ 8 indicating severe impairment.

Patients with r-axSpA performed worse than those with nr-axSpA in ASDAS ($p=0.019$), BASFI ($p=0.034$), and BASMI ($p=<0.001$), while BASDAI, ASAS HI, ASPI, and SPPB were comparable in these groups (Table 1) though only 3 (11%) patients with nr-axSpA were unable to perform all ASPI items as compared to 22 (42%) patients with r-axSpA. Most patients were excluded due to inability to perform item 2 of the ASPI (putting on socks standing up) (Supplemental Table 1).

Effects of MRCT on disease-related outcomes

All 80 patients completed the MRCT, patient-reported outcomes (PROs) of 12 patients were not included in the statistical analysis due to missing data. However, they were included in the statistical analyses of function and mobility. Significant differences between V1 and V2 were seen for physical function (BASFI $p=<0.001$) and disease activity (BASDAI $p>0.001$). BASMI sum scores improved significantly ($p=0.004$) but single BASMI items improved significantly only for intermalleolar distance and cervical rotation (all $p \leq 0.001$), whereas flexion, lateral flexion, and tragus-to-wall distance only showed a numerical improvement (Table 2).

The performance-based measures of ASPI ($p<0.001$) and SPPB ($p<0.001$) showed a very clear improvement between V1 and V2 (Table 2). Additionally, three more patients were able to perform all ASPI items after MRCT (Supplemental Table 1).

The RoM measured by the ES significantly improved for rotation and lateral flexion to both sides and only numerically for flexion and extension (Table 3). Of interest, the ES scores of RoK also showed a statistically significant improvement in velocity (Table 3). The results were consistent in the additionally performed Wilcoxon test (Supplemental Tables 2 and 3).

Table 1. Patient's demographics and assessments.

	axSpA	r-axSpA	nr-axSpA	*p*
N [a] (%)	80	53 (66.3%)	27 (33.7%)	–
Age (years)	46.6 ± 11.3	47.4 ± 11.5	45.07 ± 10.9	0.391
Male, *n* (%)	59 (73.8%)	45 (84.9%)	14 (51.9%)	0.001[b]
First onset of symptoms[a] (years)	18.8 ± 11.3	20.36 ± 12.2	15.74 ± 8.8	0.084
Disease duration[a] (years)	10.7 ± 9.8	12.1 ± 11.1	8.0 ± 6.0	0.035
HLA-B27 positive, *n* (%)	59 (73.8%)	45 (84.5%)	14 (51.9%)	–
Body mass index[a] (kg/m²)	28.2 ± 5.3	29.6 ± 5.5	25.5 ± 3.6	<0.001
CRP[a] (mg/L)	10.9 ± 22.9	14.1 ± 27.3	4.8 ± 6.8	0.022
ASDAS[a,c]	3.2 ± 0.8	3.3 ± 0.9	2.9 ± 0.6	0.019
BASDAI[a,c], 0–10	5.5 ± 1.5	5.5 ± 1.5	5.4 ± 1.5	0.760
BASFI[a,c], 0–10	5.6 ± 2.0	6.0 ± 2.0	5.0 ± 1.8	0.034
BASMI[a], 0–10	4.2 ± 1.8	4.8 ± 1.8	3.1 ± 1.1	<0.001
ASAS HI[a,c], 0–17	8.7 ± 3.2	8.9 ± 3.2	8.4 ± 3.0	0.478
ASPI[a], time in seconds	37.3 ± 18.1	38.3 ± 21.2	36.0 ± 13.3	0.652
SPPB, 0–12	10.1 ± 1.5	10.0 ± 1.5	10.2 ± 1.3	0.559
NSAIDs, *n* (%)	57 (71.3%)	36 (67.9%)	21 (77.8)	0.357[a]
Biologics, *n* (%)	43 (53.8%)	29 (54.7%)	14 (51.9%)	0.808[a]

[a]Variables are mean ± standard deviation if not otherwise indicated.
[b]Calculated using Pearson-Chi-square.
[c]Items missing data, *n* = 68.
ASAS HI, Spondyloarthritis International Society Health Index; ASDAS, AS Disease Activity Score; ASPI, the AS physical performance index; BASDAI, Bath AS Disease Activity Index; BASFI, Bath AS Functional Index; BASMI, Bath Ankylosing Spondylitis (AS) Metrology Index; CRP, C-reactive protein; NSAIDs, non-steroidal anti-inflammatory drugs; NRS, numerical rating scale; nr-axSpA, non-radiographic axial spondyloarthritis (axSpA); r-axSpA, radiographic axSpA; SPPB, Short Physical Performance Battery.

The performance-based tests ASPI and SPPB (Table 2) as well as the RoK measurements with the ES which are all based on speed of mobility showed a significant improvement in all assessments (Table 3). Thus, the results for patients with r- and nr-axSpA were rather similar. However, in nr-axSpA patients the ES measures of spinal mobility with RoM only improved numerically (Supplemental Table 4).

Subanalyses showed no relevant impact of medication on PRO's, BASMI, ASPI, SPPB, and RoM and RoK with the ES, not for stable medication or with changes of biologics or NSAIDs (Supplemental Tables 5–8).

Discussion

The two most important aims of this study (i) confirmed the effect of a standardized 2-week MRCT on function and mobility in patients with axSpA by adding assessments with an objective device in addition to all standardized measures and (ii) showed that measurements with the ES device are sensitive to change. Even though we had no control group we think that the data

Table 2. Metric assessments and patient-reported outcomes before and after MRCT.

	V1	V2	Mean difference	*p*	Effect size
Lumbar flexion (cm)	4.3 ± 2.2	4.4 ± 2.0	0.1 ± 1.4	0.521	0.07
Lateral flexion (cm)	9.7 ± 4.6	10.4 ± 5.3	0.7 ± 3.3	0.065	0.21
Tragus to wall distance (cm)	16.0 ± 6.6	16.2 ± 6.9	0.2 ± 3.3	0.675	0.05
Intermalleolar distance (cm)	90.3 ± 21.5	94.3 ± 21.8	4.1 ± 10.3	<0.001	0.40
Cervical rotation (degree)	46.3 ± 18.4	53.2 ± 19.6	6.9 ± 11.5	<0.001	0.60
BASMI	4.2 ± 1.8	3.9 ± 1.9	0.4 ± 0.8	<0.001	0.47
SPPB	13.8 ± 1.8	14.8 ± 1.8	−1.0 ± 1.6	<0.001	−0.66
ASPI in seconds[a]	34.6 ± 11.6	24.4 ± 6.1	10.2 ± 8.1	<0.001	1.27
BASDAI[b]	5.4 ± 1.5	4.3 ± 1.7	1.1 ± 1.2	<0.001	0.91
BASFI[b]	5.6 ± 2.0	4.8 ± 2.2	0.8 ± 1.4	<0.001	0.57
ASAS HI[b]	8.6 ± 3.1	8.1 ± 3.7	0.5 ± 2.3	0.08	0.25

Variables are mean ± standard deviation unless otherwise indicated.
[a]Sample size varies: *n*(V1) = 53; *n*(V2) = 56.
[b]Items missing data: *n* = 68.
ASAS HI, Spondyloarthritis international Society Health Index; ASPI, Ankylosing Spondylitis Performance-based Improvement; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; BASMI, Bath Ankylosing Spondylitis Metrology Index; MRCT, multimodal rheumatologic complex treatment; SPPB, Short Physical Performance Battery.

clearly show that MRCT improves most assessments. Regarding the improvement of mobility performance-based assessments, the composite measures, SPPB and ASPI, demonstrated moderate to large effect sizes (SPPB: 0.66; ASPI: 1.15). The effect sizes for single ES measures of RoM and RoK were comparatively smaller (<0.5). An advantage of employing electronic measures lies in their minimal inter- and intra-rater variability, thereby ensuring excellent reproducibility.

Until now the velocity of spinal mobility has not been much in the focus of clinical trials, but the results of this study clearly indicate that this outcome parameter deserves more attention.

Patients with axSpA do have impairments of spinal RoK, but the impact of the disease on RoK is not well understood. As previously shown, patients with axSpA are generally less physically active, have often more muscle weakness and sarcopenia as compared to healthy controls, but these effects are more pronounced in older patients with longstanding disease.[24,46–50] There is some evidence that gait is altered in patients with axSpA leading to reduced speed, cadence, stride length, and swing time.[51,52]

Our study also confirms the positive effect of the 2-week exercise program MRCT on spinal mobility and function which is strongly supported by the RoM and RoK scores obtained with the ES after this program. As already mentioned, the higher velocity reached in performance-based tests clearly shown by the electronic ES measures is relatively new and it clearly deserves more study. However, it does make perfect sense that intensive exercise leads to better results in performance-based tests.

Importantly, our data also show that the ES measurements are sensitive to change. This is relevant for clinical studies where more objective parameters are needed to document the success of an intervention.

As shown previously, patients with nr-axSpA have better spinal mobility and function as patients with r-axSpA – and this has also been shown using

Table 3. ES: Range of motion and range of kinematics before and after MCRT in patients with axSpA.

axSpA (*n* = 72)					
	V1	**V2**	**Mean difference**	***p***	**Effect size**
Flexion (RoM)	28.5 ± 14.3	29.4 ± 14.4	−0.8 ± 7.7	0.361	−0.11
Extension (RoM)	10.2 ± 7.7	11.1 ± 8.0	−0.8 ± 4.8	0.140	−0.18
Rotation (RoM)	13.5 ± 6.7	15.6 ± 7.9	−2.1 ± 6.4	0.007	−0.33
Rotation left (RoM)	13.6 ± 7.1	15.3 ± 8.0	−1.7 ± 6.9	0.042	−0.25
Rotation right (RoM)	13.7 ± 6.9	16.1 ± 8.5	−2.3 ± 7.0	0.007	−0.33
Lateral flexion (RoM)	11.4 ± 6.4	12.5 ± 7.4	−1.1 ± 3.3	0.008	−0.33
Lateral flexion left (RoM)	11.3 ± 6.9	12.5 ± 7.5	−1.1 ± 3.9	0.016	−0.29
Lateral flexion right (RoM)	11.5 ± 6.2	12.5 ± 7.6	−1.0 ± 3.6	0.020	−0.28
Flexion (RoK)	28.4 ± 16.1	34.0 ± 19.6	−5.6 ± 12.0	0.000	−0.47
Extension (RoK)	13.0 ± 9.0	16.1 ± 9.8	−3.1 ± 7.3	0.001	−0.42
Rotation (RoK)	20.9 ± 14.7	29.4 ± 21.6	−8.5 ± 20.3	0.001	−0.42
Rotation left (RoK)	20.7 ± 14.9	28.5 ± 21.3	−7.8 ± 20.7	0.002	−0.38
Rotation right (RoK)	21.5 ± 16.5	30.7 ± 23.9	−9.2 ± 23.3	0.001	−0.39
Lateral flexion (RoK)	21.4 ± 14.9	27.5 ± 19.7	−6.1 ± 17.2	0.004	−0.35
Lateral flexion left (RoK)	21.4 ± 16.1	27.5 ± 19.8	−6.1 ± 17.6	0.005	−0.35
Lateral flexion right (RoK)	21.4 ± 14.8	27.5 ± 20.2	−6.1 ± 18.0	0.006	−0.34

Results as mean ± standard deviation in angular degree unless otherwise indicated effect size (<0.5 = low effect, 0.5–0.8 = moderate effect, >0.8 = high effect).
ES, Epionics SPINE; MRCT, multimodal rheumatologic complex treatment; nr-axSpA, non-radiographic axial spondyloarthritis (axSpA); r-axSpA, radiographic axSpA; RoM, range of motion; RoK, range of kinematics.

the ES.[25,34] Our results are much in line with these studies, including the ASPI and SPPB. Since spinal mobility depends on inflammation and structural damage in the axial skeleton, it is comprehensible that patients with nr-axSpA have less problems in this regard since they do not have structural changes in the SIJ and in most cases also in the spine.[10] Nevertheless, nr-axSpA patients improved remarkably – especially in performance-based tests and also in RoK as assessed with the ES indicating improved velocity.

Our MRCT-program combines different aspects and domains of PA including cardiovascular training, muscle strength, and cognitive behavioral therapy. Because of the multimodal strategy followed we are unable, at this point in time, to determine which interventions are best. We believe that patients benefit variably from different types of interventions, which clearly makes this program stronger as compared to programs without multimodal strategies.

In this study, the intake or changes of medication did not seem to be a relevant factor for results related to mobility.

However, the long-term effect of anti-inflammatory medication on velocity has not been investigated to date.

In accordance with our results, other studies with non-medical interventions have also shown positive effects on physical function and mobility. For example, a recent program with high-intensity PA did not only have a positive impact on function and mobility but also on disease activity.[15,16] The beneficial effects of inpatient programs, also on global functioning and well-being have also been previously demonstrated.[30,53]

In line with these data, our study clearly shows beneficial results for patients with axSpA participating in this intensive in-patient program. However, it is not clear how long these positive effects last and whether it was possible to motivate patients to keep up with PA. Thus, follow up and long-term studies are needed to shed light on these important questions.

A limitation of this study is the lack of a control group. Control groups could for example contain patients who did not perform any exercise over 2 weeks or patients who just performed PA as ususal or patients doing a program on an outpatient basis. Both are not so easy to organize but possible. However, patients who do not exceed their daily recommended level of PA are unlikely to experience a significant improvement in mobility and overall function within 2 weeks.

On the other hand, we acknowledge the potential limitation of 'learned behavior' in relation to both PA and performance-based tests. Patients may improve their performance in these tests simply because of repeating them and, thus, becoming more skilled over time. However, as previously demonstrated, the correlation for repeated measurements on three different days (within 5 days, same time of the day) has been pretty good – with an average correlation coefficient of 0.84.[36] Furthermore, this study may just prove short-term effects of the MRCT. Another study visit was planned 3 months later but due to the unexpected start of the pandemic with associated hospital regulations and patients' unwillingness to entering a hospital, we have only data of less than 30% patients performing all tests after 3 months again and therefore no robust statistic could be performed.

In conclusion, these study results indicate that performance-based tests and RoK measurements are relevant outcome-parameters for clinical trials. Assessments with the ES are sensitive to change. The MRCT program was shown to work in active axSpA patients. All currently available data favor PA as an important intervention not only in this disease.

Declarations

Ethics approval and consent to participate

The Ethical Committee of the Ruhr University approved the study (reference number 19-6735-BR). Written informed consent was obtained from all patients.

Consent for publication

Not applicable.

Author contributions

David Kiefer: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

Lucia Schneider: Formal analysis; Investigation; Writing – original draft; Writing – review & editing.

Juergen Braun: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

Uta Kiltz: Conceptualization; Investigation; Methodology; Supervision; Writing – original draft; Writing – review & editing.

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Xenofon Baraliakos: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

Acknowledgements
None.

Funding
The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Novartis, Germany by an unrestricted grant. The investigators retained full control of scientific and analytic content, and had final editorial responsibility.

Competing interests
The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: DK has received grant and research support and consultancy fees from AbbVie, BMS, Boehringer Ingelheim, Chugai, Eli Lilly, Galapagos, Janssen, MSD, Novartis, Pfizer, Roche, and UCB. JB has received honoraria for talks, advisory boards, paid consultancies, and rants for studies from Abbvie (Abbott), Amgen, Baxter, Biogen, BMS, Boehringer, Celgene, Celltrion, Centocor, Chugai, Hexal, Janssen, Lilly, Medac, MSD (Schering-Plough), Mylan, Mundipharma, Novartis, Pfizer (Wyeth, Hospira), Roche, Sanofi Aventis, and UCB. UK has received grant and research support and consultancy fees from AbbVie, Amgen, Biogen, Chugai, Eli Lilly, Fresenius, Grünenthal, GSK, Hexal, Janssen, MSD, Novartis, Pfizer, Roche, and UCB. NK: None. LS: None. IA has received research support, consultancy fees, and honoraria from Abbvie, Amgen, BMS, Chugai, Janssen, Eli Lilly, MSD, Novartis, Pfizer, Sobi, Takkeda, and UCB. ST: None. BB has received honoraria for talks, advisory boards, paid consultancies, and/or travel support from Abbvie, Alexion, Amgen, Biogen, Boehringer Ingelheim, Gilead/Galapagos, Janssen, MSD, Theramex, Sanofi-Genzyme, and UCB. PS has received grant and research support and consultancy fees from AXIOM Health, AMGEN, AbbVie, Biogen, Bristol-Myers Squibb, Celgene, Chugai Pharma Marketing Ltd/Chugai Europe, Deutscher Psoriasis-Bund, Gilead Sciences, Hexal Pharma, Janssen-Cilag, Johnson & Johnson, Lilly/Lilly Europe/Lilly Global, medi-login, Mediri GmbH, Novartis Pharma, Onkowissen GmbH, Pfizer, Roche Pharma, Rheumazentrum Rhein-Ruhr, Sanofi-Genzyme, Spirit Medical Communication, Swedish Orphan Biovitrum, UCB Pharma. SH: Has received consultancy fees of AbbVie and Novartis. XB has received grant and research support and consultancy fees from AbbVie, Amgen, Chugai, Galapagos, Hexal, Lilly, MSD, Novartis, Pfizer, and UCB.

Availability of data and materials
Availability of data and materials: all data generated or analyzed during this study are included in this published article.

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Supplemental material
Supplemental material for this article is available online.

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