Validity and Feasibility of Remote Measurement Systems for Functional Movement and Posture Assessments in People with Axial Spondylarthritis

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June 18, 2022

Abstract

Introduction Axial spondylarthritis (axSpA) is a chronic inflammatory disease and commonly results in pain and joint stiffness. Using remote technology, such as a computer vision-aided system, has the potential to monitor functional movement and posture. Methods The validity of the remote technology measurement of functional movement and posture were tested cross-sectionally and compared to a standard clinical measurement by a physiotherapist. The feasibility of remote implementation was tested in a home environment. In addition, a cost-benefit analysis was conducted. Results Thirty-one participants with axSpA (42% female, 54(SD 13) years old and 27.4(SD 5.3) kg/m2) and 31 participants without back pain (65% female, 36(SD 10) years old and 25.9(3.7) kg/m2). In the axSpA group, the validity of assessment on cervical rotation, lumbar flexion, lumbar side flexion, shoulder flexion, hip abduction, tragus-to-wall and thoracic kyphosis showed significant moderate to strong correlation; in the non-back pain group, the same measures showed significant correlation ranging from weak to strong. Conclusions Remote technology systems in rehabilitation have the potential to reduce health inequality and improve cost and time effectiveness for both patients and the health system. Additionally, results show that using this Computer Vision-aided system in a home environment is a safe method.

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Thirty-one participants with axSpA (42% female, 54(SD 13) years old and 27.4(SD 5.3) kg/m^2) and 31 participants without back pain (65% female, 36(SD 10) years old and 25.9(3.7) kg/m^2). In the axSpA group, the validity of assessment on cervical rotation, lumbar flexion, lumbar side flexion, shoulder flexion, hip abduction, tragus-to-wall and thoracic kyphosis showed significant moderate to strong correlation; in the non-back pain group, the same measures showed significant correlation ranging from weak to strong.

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Introduction

Back pain is one of the most common health problems, and an estimated one-third of adults in the UK are affected each year. One condition that causes chronic back pain is axial spondylarthritis (axSpA). This chronic inflammatory disease primarily affects spinal joints, resulting in pain and joint stiffness symptoms and altered posture. AxSpA affects approximately 5 in 1,000 adults in the UK and is a condition that encompasses both people with ankylosing spondylitis (AS), defined by radiographic evidence of structural changes, and people with non-radiographic axial spondyloarthritis. Inflammation of the axial spine results in a clinical presentation of pain and reduced spinal mobility which is often misdiagnosed or overlooked. Symptoms of axSpA first present as inflammatory back pain in people during the third decade of life, impacting on work, family and social commitments causing both economic and humanistic burden. The clinical presentation requires both drug and non-drug management with regular follow-up to optimise therapy.

To clinically identify the pattern and severity of reduced joint mobility, multiple tools have been developed to objectively assess these restrictions in the axSpA population. The most common non-radiographic clinical assessment tool is the Bath Ankylosing Spondylitis Metrology Index (BASMI), an index of five simple clinical measurements to assess the axial status. The Edmonton Ankylosing Spondylitis Metrology Index (EDASMI) is an index of four similar clinical measurements that was developed to be more responsive to change than the BASMI yet is less widely used. In further effort to increase measurement precision of the clinician-administered BASMI and EDASMI, the University of Cordoba Ankylosing Spondylitis Metrology Index (UCOASMI) was developed to measure by automated motion capture using four cameras and 33 reflective markers placed on anatomical landmarks. More recently, inertial measurement unit (IMU) sensor-based systems have been employed to measure spinal mobility using five IMUs attached along the spine.

These tools and methods described require either a clinician for measurement or specialised equipment, e.g., motion capture system or IMUs and analytic expertise. Therefore, usability and acceptability are a limitation that may prevent regular monitoring. More remote systems, for example, markerless pose estimation using computer-vision, have evolved with the potential to be used directly by patients to enhance telerehabilitation. Computer-vision (CV) is a branch of artificial intelligence that can be used to automate analysis of human movement analysis from videos. By using CV-aided methods to analyse specific functional movements captured on video, both clinicians and patients can have access to a powerful tool that could bridge the gap between the clinic and home. In addition to functional movement, postural deficits are present in people with axSpA; therefore, monitoring posture with a remote system using a surface topography tool could be important and valuable. This CV-aided system may also have the potential to be a more cost-effective method to evaluate and monitor people with axSpA compared to an in-person clinician assessment. Remote and automated monitoring technology has the potential to work alongside the clinical team by identifying when there have been significant changes in joint mobility and posture. Therefore, reducing clinician time and decreasing unnecessary traveling, reducing health system pressures while at the same time creating the opportunity for more frequent access and greater accessibility to better management.

This study aimed to estimate the criterion validity of functional movement and posture measurement using remote technology systems in people with and without axSpA by comparing them to measurements performed by a trained clinician. The secondary aims were to determine the systems' accuracy as a potential measure of functional activity, to understand the feasibility of implementing remote technology systems in the laboratory and home environments, and to estimate the cost consequences of the remote technology systems compared to a face-to-face clinical visit.

Methods

Study design

This study was a two-part cross-sectional observational study. In part one, the criterion validity was measured in a movement laboratory setting with measurement by an experienced physiotherapist established as the reference test. Subsequently in part two, the same participants captured videos in their home for additional CV-aided analyses, which was used to help assess the feasibility in the home environment. The study was conducted and evaluated according to the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) pathway for validity and reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement. Ethical approval was granted by the University Research Ethics Committee (reference: 201429), and the study was conducted in compliance with the Declaration of Helsinki.

Participants

The study included men and women aged 18 years or older who were willing and capable of uploading videos from a smartphone or webcam. People with axSpA were recruited through the local National Axial Spondylosis Society (NASS) network, and people who reported no long-standing back pain were recruited through social media and advertisement. Individuals were excluded from participation if they had surgery within six months, were unable to stand independently, were unable to pass screening questions to participate in physical activity (Physical activity readiness questionnaire, PAR-Q), had a serious neurological condition preventing normal movement or walking ability, or had any severe medical conditions. A minimum of 17 participants were required per group (axSpA and non-back pain groups), assuming 1-beta =0.90, alpha=0.05 and effect size $|\rho|$=0.50.

Methods of measurement

The CV-aided system approach (Good Boost CV system, Good Boost Wellness, UK, 2021) in this study involved a modified version of OpenPose, a computer vision algorithm trained to detect key landmarks on the human body within camera images. For a given frame of image/video data, OpenPose returns predicted x,y coordinates for each body part and each human detected in the image. X,y coordinates were used to compute metrics such as joint angles and distances (in pixels) between two body parts for the index of movements. To translate distance values into real-world distances, at the start of each movement, the participant or investigator held up a calibration checkerboard parallel to the camera and at the same distance at which the movement was performed; Python's OpenCV package was used to automatically detect the corners of the checkerboard to scale all distance values from pixels to centimetres. The videos taken in the movement laboratory were captured by a Logitech C920 pro HD webcam (©2021 Logitech, UK) with 1080p resolution and 30 frames per second sampling rate. The videos taken in the home setting were captured by the participant's smartphone camera, tablet camera or webcam. Spinal curvature was measured in the laboratory only using a portable surface topography method employing the Microsoft Kinect sensor V2 (Microsoft Corporation, Seattle, Washington, U.S.A) and using an established method to measure thoracic kyphosis. The reference tests were a series of standard clinical assessments measured by an experienced physiotherapist who was blinded to the remote technology systems analyses and results.

Research visit

During the visit, conducted in a university movement laboratory, the following self-reported disease-specific questionnaires were collected: Bath AS Functional Index (BASFI), composed of 10 questions about functional limitation; the Bath AS Disease Activity Index (BASDAI), composed of six questions pertaining to fatigue, spinal pain, joint pain/swelling, areas of localised tenderness and morning stiffness; and the Bath AS Patient Global score (BAS-G) which asks about the person's well-being over the past week and the past six months. Along with height and weight, spatiotemporal gait data was captured using an IMU (LPMS-B2, Life Performance Research, Japan) placed on projected centre of mass (L4). The standardised index of functional tests (Table 1) was instructed and measured by an experienced physiotherapist, then performed and captured by video recording for CV-aided analysis. Following the laboratory research visit, the participant performed and captured video of the same index of tests at their home using a personal smartphone camera, tablet camera or webcam. (Figure 1)

Outcome measures for criterion validity

Videos were captured in the laboratory and home environments for the following index of tests which were derived from BASMI and EDASMI: lumbar side flexion, lumbar forward flexion, tragus-to-wall distance, cervical rotation seated, hip internal rotation, hip abduction standing, shoulder flexion and 5 times sit-to-stand (5xSTS). Standing posture was captured by the Kinect sensor. The index of tests was also measured in the laboratory by the physiotherapist. These tests were selected based on their relevance and representation in the BASMI and EDASMI and narrowed down based on the practicality of administration after trialling all functional tests in both the laboratory and home settings.

Feasibility

Several metrics were collected to measure the feasibility of the CV-aided system in terms of the practicality and acceptability of performing the tests in both home and laboratory settings. The completion rate of outcome measures for both settings were recorded to help gain understanding about the internal and external barriers to implementation.

Cost-consequence analysis

In order to analyse the cost-benefits of a face-to-face clinical assessment and an automated, remote CV-aided assessment, the direct costs and those of travel assuming that assessments take place in a regional specialist service requiring an estimated travel of 30 miles roundtrip at £0.42/mile and associated carbon cost (average cost of CO_2 emissions per car is 221.4 g/mile at £68/CO_2 were calculated using two methods to estimate the difference in cost per assessment. Additionally, associated benefits were compared.

Statistical analysis

All the data was coded anonymously. The Shapiro-Wilk test confirmed that all data were normally distributed. Missing value analysis confirmed that missing data was randomly distributed and excluded for the comparisons. Descriptive statistics for each group were analysed and reported in the results with their mean (SD); independent sample t-test was used to compare the group means. Pearson's correlation analysis were used to compute the correlation between the two methods in each group, and Bland-Altman plot analysis used to estimate the agreement within the axSpA cohort. Correlation coefficients 1.00 to 0.90 were interpreted as very strong, 0.89 to 0.70 as strong, 0.69 to 0.50 as moderate, 0.49 to 0.30 as weak, and 0.29 to 0 as very weak. Frequencies and percentages were used to summarise the feasibility data. P values <0.05 were considered statistically significant, and all tests were 2-tailed. Statistical analyses were performed using SPSS version 28 (IBM SPSS Statistics).

Results

Sixty-two participants (53% female) with a mean age of 45 (SD 14) years completed the study; there were 31 participants with axSpA (42% female, 54 (SD 13) years old) and 31 non-back pain participants (65% female, 36 (SD 10) years old). The axSpA group had more functional limitation, higher disability and a slower walking speed compared to the non-back pain group (Table 2). The axSpA group demonstrated more limited range of motion in the lumbar, shoulder and hip joints, and increased thoracic kyphosis and forward head posture compared to the non-back pain group (Table 3).

Validity of remote systems

Cervical rotation measurement by the CV-aided system was moderately correlated to a clinician assessment in the axSpA group and weakly correlated in the non-back pain groups (Table 4); in the axSpA group, the CV-aided system demonstrated a –2.6cm bias compared to the reference physiotherapist measurement with a positive regression slope (Figure 2). Lumbar forward flexion and hip internal rotation were strongly correlated in both the axSpA and non-back pain groups; both demonstrated a postive bias (+0.4cm and +3.7cm, respectively) with one outlier beyond the limits of agreement. Shoulder flexion and lumbar side flexion showed a strong to very strong correlation in axSpA group and moderate to weak correlation in non-back pain group. Shoulder flexion demonstrated a negative bias (right –3.0 degrees, left –1.4 degrees) with a slightly negative slope, and lumbar side flexion demonstrated minimal bias (right –0.6cm, left 0cm). Hip abduction was moderately correlated in axSpA group and demonstrated moderate to strong correlation in the non-back pain group. Metrics for posture showed strong correlation for tragus-to-wall distance (TWD) and thoracic kyphosis measurement in the axSpA group, yet very weak (TWD) to moderate (kyphosis) correlation in the non-back pain group; lumbar lordosis was not significantly correlated in either group (Table 4). All measurements showed agreement in the axSpA group with minimal bias (TWD –0.9, kyphosis +0.4, lordosis +0.2); TWD has a positive slope and kyphosis and lordosis have negative slopes, all with few outliers (Figure 3).

Feasibility of video capture in home setting

A total of 23 participants (74%) of 31 from the axSpA group uploaded their home recorded videos, and one participant did not use their calibration grid correctly during the videos. Based on these participants, the CV-aided system produced an output in 84% for tragus-to-wall, 76-84% for shoulder flexion, 84% for lumbar forward flexion, 84-88% for lumbar side flexion, 84-88% for hip abduction, 88% for cervical rotation, 88% for hip internal rotation, and 80% for the 5xSTS. Thirty non-back pain participants (96%) out of 31 uploaded their videos; one participant did not use utilise their calibration grid in the videos. Data from uploaded videos could be analysed for 71% for tragus-to-wall, 77% for shoulder flexion, 84% for lumbar forward flexion, 81-84% for lumbar side flexion, 87% for hip abduction, 84% for cervical rotation, 84% for hip internal rotation, and 87% for 5xSTS.

Cost-consequence analysis

This cost analysis compared the CV-aided system to the current clinical assessment costs that would incur in the UK's national health system. The results indicate that using this remote computer vision application could save £64.70 for each participant per session with environmental, economic and social benefits (Table 5).

Discussion

The study findings suggest that remote measurement systems are valid and cost-effective options to estimate functional movement and posture in people with axSpA. Specifically, the validity results suggest there is moderate to strong correlation and agreement between a majority of functional movements and postural alignment compared to a standard clinician assessment. The strongest correlational relationships were shown in lumbar forward flexion, lumbar side flexion, shoulder flexion, hip internal rotation, tragus-to-wall, and thoracic kyphosis, particularly in people with axSpA. The only test from either a functional movement or posture that showed no correlation between methods was found in the lumbar lordosis, which was consistent between the axSpA and non-back pain groups.

The two groups demonstrated expected clinical presentation differences, including higher BASDI and BASFI scores and more restricted range of motion and hyperkyphosis in the axSpA group. The limited range of motion among the axSpA group in all functional movements tested demonstrates the broader use of this technology in clinical groups that fall outside the normal range of motion. In the end, the results did indicate varied correlative relationships between the axSpA and non-back paing groups in several functional movement and postural tests, notably shoulder flexion, lumbar side flexion, tragus-to-wall and kyphosis. In both shoulder flexion and lumbar side flexion, the axSpA group had smaller ranges of motion compared to the non-back pain group and stronger correlation ($r = .787$-$.906$) between the CV-aided system and clinical measurement compared to the non-back pain group ($r = .468$-$.655$). One reason for this discrepancy could be due to altered anatomical landmark visibility or increased trunk compensation in higher ranges of motion as were seen in the non-back pain group. Posture measurement demonstrated similar incongruence; there was a stronger correlation in the axSpA group, who presented with more kyphotic and forward flexed posture compared to the non-back pain group. This discrepancy could stem from less accurate and reliable measurement of smaller kyphosis curvature, which is one limitation of the tragus-to-wall test which has a floor effect.

The tests that did not demonstrate strong correlation were hip abduction, cervical rotation and lumbar lordosis posture. Hip abduction was adapted into a standing test to provide a more practical testing position for video recording compared to the BASMI hip mobility test, where the patient is lying on the ground and abducting both hips to their maximum range. Although more practical to perform, standing hip abduction has challenges that include both the participant performing it correctly and the landmarks needed for automation. Participants often compensate during standing hip abduction by either elevating their ipsilateral hip or externally rotating their hip. If the clinician does not correct the compensatory movements, it could cause an overestimation of the range. Similarly, the compensatory movements can cause an overestimation or inaccurate landmark identification by the CV algorithm. Cervical rotation in a seated position with a tape measure was also chosen for its practicality. This test was taken from the EDASMI since the supine cervical rotation test in the BASMI similar camera positioning challenges as the hip mobility test. The difficulty with frontal plane measurement of a rotational movement was demonstrated in the lack of a strong correlation between the CV-aided system and clinician measurement, in both groups. Lastly, the lumbar lordosis postural alignment measured by surface topography using the Kinect sensor showed agreement, but no correlation and no significant difference between groups. This could be on account of the documented difficulty of measuring lumbar lordosis with surface measurement tools, and the practicality of clothing interference in some participants during the testing.

An important aspect of this study was the feasibility of the CV system in a home setting because of the potential for many benefits of remote testing. The first barrier for the participants was uploading the videos, which was less successful in the axSpA group (n=8 missing) than the non-back pain group (n=1 missing). Developing a user-friendly interface for uploading videos would lower the barrier for home use. Two other aspects of feasibility at home were the ability of participants to successfully record the correct movement and the quality of the videos for automated CV analysis. More than 70% of the recorded videos were useable. The reasons for non-usable data were incorrect use of the calibration grid, camera movement and incompatible data format from one participant's smartphone. These issues could be addressed by improving instructions and calibration method. Pragmatic use of this technology at home would be a key to helping people, with and without back pain, track and maintain functional movement, range of motion and posture with the option of remote clinician support. Not only does this remote system widen accessibility to specialists who may not be local, it is a cost-efficient method and has many social and environmental benefits. It can benefit both patients and the health system in terms of time and opportunity. Furthermore, it can have a positive environmental impact by reducing the carbon footprint associated with each face-to-face visit. For the appropriate patient, it could result in a cost savings of £64 per assessment. While these results look specifically at people with axSpA, it can reasonably be generalised to similar long-term musculoskeletal conditions.

Limitations

The limitations of this study include the relatively small sample size and the cross-sectional method. While it was not possible for simultaneous measurement from the clinician and video, the repetitions were performed within the same session under the same conditions. Further studies would benefit from repeated testing to measure the sensitivity to change of these remote technologies.

Conclusions

Using a clinically-validated computer vision system in rehabilitation has the potential to reduce inequality in the health system and make it more cost and time effective for both patients and the health system. In addition to demonstrating validity in most of the functional and postural measures, results show that using this CV-aided system in a home environment is a safe and feasible method which can widen accessibility and affordability.

References

Table 1. Description of tests

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Test

Brief description

Lumbar side flexion

Active ROM test for standing lateral side flexion; distance of hand displacement measured in cm.

Lumbar forward flexion

Active ROM test for forward flexion; distance of fingertips to lateral malleolus measured in cm.

Tragus-to-wall

Standing global forward posture; horizontal distance from wall measured in cm.

Cervical rotation (seated)

Active ROM test of cervical rotation; distance displacement between suprasternal notch and the tragus of the right ear measured in cm.

Hip internal rotation

Active ROM test of bilateral internal rotation in a seated position; distance between medial malleoli measure in cm.

Hip abduction

Active ROM test of hip abduction in standing position; angle between level of ASIS and femur measured in degrees.

Shoulder flexion

Active ROM test of shoulder flexion; angle between torso and humerus measured in degrees.

5xSTS

Functional test of lower extremity strength by recording the time taken to complete 5 sit-to-stand repetitions.

Standing posture

Measurement of thoracolumbar spinal posture; physiotherapist measurement using flexicurve and surface topography using Kinect sensor both measured kyphosis index.

Table 2. Participant characteristics and temporal walking parameters based on gender and health condition.

Health Condition	Health Condition	Health Condition	BMI (SD) [kg/m^2]	Height (SD) [cm]	Weight (SD) [kg]	Cadence (SD) [steps/min]	Walking speed (SD) [m/s]	Step time (SD) [ms]	BA sco [hi sco low fun
Non-back pain group	Male	Mean	27.57 (3.57)	179.5(4.7)	88.9 (12.1)	108.71 (6.92)	1.44 (0.17)	556.92 (37.12)	3.6 (5.
		N	11	11	11	11	11	11	11
	Female	Mean	25.00 (3.48)	165.1 (7.8)	67.8 (8.1)	114.66 (9.34)	1.36 (0.16)	532.92 (37.08)	3.8 (5.
		N	20	20	20	20	20	20	20
	Total	Mean	25.91 (3.67)	170.2 (9.8)	75.3 (14.0)	112.55 (8.92)	1.39 (0.16)	541.43 (38.29)	3.7 (5.
		N	31	31	31	31	31	31	31
AxSpA group	Male	Mean	27.34 (3.24)	177.2 (7.9)	86.3 (15.5)	109.59 (8.29)	1.36 (0.16)	553.21 (39.09)	33. (21
		N	18	18	18	18	18	18	18
	Female	Mean	27.37 (7.43)	159.6 (9.3)	68.6 (14.6)	110.56 (6.25)	1.23 (0.15)	547.34 (32.36)	37. (19
		N	13	13	13	13	13	13	13
	Total	Mean	27.35 (5.30)	169.8 (12.2)	78.9 (17.3)	110.00 (7.41)	1.31 (0.17)	550.74 (35.97)	35. (20
		N	31.00	31	31	31	31	31	31
Total	Male	Mean	27.43 (3.31)	178.1 (6.9)	87.3 (14.1)	109.26 (7.68)	1.39 (0.16)	554.62 (37.73)	22. (22
		N	29	29	29	29	29	29	29
	Female	Mean	25.93 (5.41)	162.9 (8.7)	68.1 (10.9)	113.05 (8.40)	1.31 (0.17)	538.60 (35.50)	17. (20
		N	33	33	33	33	33	33	33
	Total	Mean	26.63(4.58)	170.0 (11.0)	77.1 (15.7)	111.27 (8.23)	1.35 (0.17)	546.09 (37.14)	19. (21
		N	62	62	62	62	62	62	62

Table 3. Movement and postural differences between groups measured by clinician assessment

Test	AxSpA group [mean (SD)]	Non-back pain group [mean (SD)]	p value
Seated cervical rotation (cm)	5.7 (1.4)	6.3 (0.8)	0.06
Lumbar forward flexion (cm)	33.5 (1.4)	18.7 (9.4)	<0.001
Hip internal rotation (cm)	36.4 (12.3)	47.4 (7.6)	<0.001
Shoulder flexion (degrees)			
Right shoulder	140.5 (21.6)	164.9 (18.7)	<0.001
Left shoulder	140.5 (26.3)	166.9 (18.8)	<0.001

Test	AxSpA group [mean (SD)]	Non-back pain group [mean (SD)]	p value
Hip abduction (degrees)			
Right hip	30.6 (10.2)	44.0 (9.9)	<0.001
Left hip	29.8 (10.1)	44.6 (8.3)	<0.001
Lumbar side flexion (cm)			
Right side	12.9 (4.6)	20.3 (4.5)	<0.001
Left side	12.4 (4.9)	19.5 (3.1)	<0.001
Tragus-to-wall (cm)	16.7 (4.0)	13.2 (1.5)	<0.001
Thoracic kyphosis (index)	11.8 (3.9)	9.1 (3.6)	0.008
Lumbar lordosis (index)	10.4 (3.2)	12.27 (4.4)	0.08

Table 4 Correlation between remote systems and clinician measurement for both groups

Test	AxSpA	AxSpA	Non-back pain	Non-back pain
	n	r, p value	n	r, p value
Seated cervical rotation (cm)	31	0.649, <0.001	31	0.443, 0.013
Lumbar forward flexion (cm)	31	0.856, <0.001	31	0.858, <0.001
Hip internal rotation (cm)	30	0.854, <0.001	31	0.846, <0.001
Shoulder flexion (degrees)				
Right shoulder	30	0.787, <0.001	26	0.468, 0.016
Left shoulder	31	0.906, <0.001	30	0.533, 0.002
Hip abduction (degrees)				
Right hip	31	0.583, <0.001	31	0.683, <0.001
Left hip	31	0.643, <0.001	31	0.720, <0.001
Lumbar side flexion (cm)				
Right side	31	0.895, <0.001	31	0.476, 0.007
Left side	31	0.842, <0.001	31	0.655, <0.001
Tragus-to-wall (cm)	31	0.872, <0.001	31	0.194, 0.002
Thoracic kyphosis (index)	27	0.705, <0.001	28	0.553, 0.002
Lumbar lordosis (index)	25	-0.272, 0.183	28	0.239, 0.221

Table 5: Comparison of costs between current clinical method and computer vision system

Assessment	Cost	Benefit
Current clinical	Physiotherapist Band 6 £52.00 Travel £12.60 Carbon footprint £0.48 Total for 1 assessment £65.08	Face-to-face interaction preferred by minority of patients [recent survey Oxon rehab services] and for complex management.

Assessment	Cost	Benefit
CV-aided system	4 assessments* £0.29 Total for 1 assessment £0.07 **Assuming 10% market of axSpA*	No travel times Minimal carbon footprint Reduced carer pressure [driving] Self-management Opportunity for more regular assessment Data can be securely transferred Expert physiotherapy for wider population, greater inclusion Saving clinical resource
Total cost savings/benefit	£64.70/assessment	Environmental Economic Social Reduced pressure on NHS

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`Figure 1 study flowchart .docx` available at https://authorea.com/users/489991/articles/573466-validity-and-feasibility-of-remote-measurement-systems-for-functional-movement-and-posture-assessments-in-people-with-axial-spondylarthritis

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`Figure 2. Bland-Altman plots for movements.docx` available at https://authorea.com/users/489991/articles/573466-validity-and-feasibility-of-remote-measurement-systems-for-functional-movement-and-posture-assessments-in-people-with-axial-spondylarthritis

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`Figure 3. Bland-Altman plots for posture.docx` available at https://authorea.com/users/489991/articles/573466-validity-and-feasibility-of-remote-measurement-systems-for-functional-movement-and-posture-assessments-in-people-with-axial-spondylarthritis