

Proposal of a linear definition of the Bath Ankylosing Spondylitis Metrology Index (BASMI) and comparison with the 2-step and 10-step definitions

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ABSTRACT

Background: The Bath Ankylosing Spondylitis Metrology Index (BASMI) characterises the spinal mobility of patients with ankylosing spondylitis. Two versions have been published using categorical scores with either scores 0–2 for each of the five assessments, or scores 0–10. For metric purposes, we recently defined a BASMI version with linear score definitions.

Aim: to evaluate agreement between three BASMI definitions and to test sensitivity to change.

Patients and methods: The performance of the BASMI₂ (based on the 2-step definition), BASMI₁₀ (based on the 10-step definition), and BASMI_{lin} (based on the linear definition), are compared in 598 status assessments and 222 follow-up assessments with a 24-week interval after an intervention with either placebo or a tumour necrosis factor (TNF) blocker from various cohorts of patients with ankylosing spondylitis (AS). Descriptive statistics and Bland–Altman plots were applied to compare the pairwise agreement of the three definitions. To assess sensitivity to change, Guyatt effect size using change data from the placebo and actively treated patients were used.

Results: Bland–Altman analysis showed that the differences between BASMI₂ scores and scores obtained by either of the two other definitions were highly dependent on the magnitude of the measurement. Guyatt effect sizes were 0.66 for the BASMI₂, 0.95 for the BASMI₁₀, and 1.04 for the BASMI_{lin}, respectively, demonstrating best sensitivity to change for the newly-developed BASMI_{lin}.

Conclusions: The BASMI₁₀ and BASMI_{lin} have clear metric advantages as compared to BASMI₂, among which are their superior sensitivity to change and feasibility of BASMI_{lin} in computer evaluations. The BASMI₁₀ and BASMI₂ are not interchangeable.

The Bath Ankylosing Spondylitis Metrology Index (BASMI) is a combined index comprising five assessments of spinal mobility in patients with ankylosing spondylitis (AS). It includes assessments of lateral lumbar flexion, tragus to wall distance, lumbar flexion, intermalleolar distance, and cervical rotation.^{1,2} These measurements were found to be most reliable and clinically useful to reflect axial status based on an extensive literature review by a group of rheumatologists, physiotherapists and research associates with a special interest in AS. In their initial validation they have shown that a combination of these 5 measures is a good reflection of the information obtained by 20 separate clinical measurements.¹ It is a useful measure for characterising the outcome of AS, comprising the effect of radiological spinal changes

and soft tissue involvement.^{3,4} The Assessment in Ankylosing Spondylitis International Working Group (ASAS) adopted the BASMI as part of their core set for spinal mobility measurements in AS.⁵

In the definition of the BASMI published in 1994¹ each continuous assessment was converted into a nominal score of 0, 1 or 2, based on the conversion table shown in table 1. The sum of these scores (BASMI₂) is also nominal and can adopt whole numbers only, with a range from 0–10.

In 1995, a second definition was published² in which each continuous assessment was converted into a nominal score of zero to 10 based on a separate conversion table shown in table 2. The sum of these scores divided by 5 (the BASMI₁₀) is also nominal in nature, thus creating a similar construct with a range of 0–10, which can adopt whole multiples of 0.2. The similar range of BASMI₁₀ and BASMI₂ suggests that these constructs would be interchangeable.

A disadvantage of both nominal definitions is that the continuous scale of the assessments is converted into a nominal one, ie, that small changes in the assessments can as well be suppressed as lead to large jumps in the resulting BASMI (theoretically up to the half scale range in worst case for BASMI₂). In intervention trials where small improvements in spinal mobility are of interest, this disadvantage can be essential. Furthermore, a computer evaluation with the discontinuous conversion is rather complicated.

Moreover, the scale range of the various spinal mobility assessments is different between the BASMI₂ and BASMI₁₀. To our knowledge, the effect on the performance of the BASMI₂ and BASMI₁₀ has never been formally compared. Though most publications involve the BASMI₂, it is often not clear to the reader of an article which of the definitions was used.

We propose here a BASMI definition that is based on continuous data, with a linear assessment to score conversion in the range 0–10. We describe its application for computer use in the analysis of clinical trials, and also its application for use without a computer “at the bedside”. We compare the performance of our definition with the existing BASMI₂ and BASMI₁₀ definitions with respect to comparability, test retest reliability and sensitivity to change by applying them in observational data and in data from patients treated with tumour necrosis factor (TNF) blockers in various clinical trials.

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Table 1 Conversion table for BASMI₂; the BASMI₂ is the sum of the five scores

If:	Then score =		
	0	1	2
Lateral lumbar flexion* (cm)	>10 cm	5–10 cm	<5 cm
Tragus-to-wall distance* (cm)	<15 cm	15–30 cm	>30 cm
Lumbar flexion (modified Schober) (cm)	>4 cm	2–4 cm	<2 cm
Intermalleolar distance (cm)	>100 cm	70–100 cm	<70 cm
Cervical rotation angle* (°)	>70°	20–70°	<20°

*For lateral lumbar flexion, tragus-to-wall distance, and cervical rotation the average of right and left should be taken.
BASMI, Bath Ankylosing Spondylitis Metrology Index.

PATIENTS AND METHODS

Proposed linear BASMI definition

The assessments *A* of the five components are converted into the scores *S* using the equations given in table 3. The factors in the equations have been chosen as to establish agreement between BASMI₁₀ and our definition for the centre of each field of the BASMI₁₀ conversion table. Like the BASMI₁₀, the BASMI_{lin} is also the average of the five scores. If the assessment results are to be evaluated by hand without a computer and the resulting BASMI_{lin} scores are to be compared with former results “at the bedside”, it is simpler and less time consuming to enter the scores into the form shown in fig 1 and to perform the conversion in a graphical way with the help of the double scales presented in this figure.

Patients and assessments

For the comparison of the performance of the three BASMI versions (BASMI₂, BASMI₁₀, and BASMI_{lin}) we used existing assessments from various cohorts. All spinal mobility assessments necessary to calculate the BASMI were made in 187 patients from the OASIS (Outcome in Ankylosing Spondylitis International Study) cohort, which was used for several previous studies.^{6–10} The assessments are performed as described in fig 1. For the cervical rotation the method with the goniometer was applied. In 154 of the 187 patients two assessments were made with a 2 year interval, and in the remaining 33 of the 187 patients a single assessment was made (in total 341 assessments).

In addition, baseline data from 257 patients that took part in three clinical trials to assess anti TNF therapy were used. In total, 598 assessments could be used for comparison of status scores according to different BASMI definitions. Moreover, 63 patients treated with placebo and 159 patients treated with anti TNF therapy had a baseline and 24 week follow up assessment available, and could be used to compare sensitivity to change of different BASMI definitions.

Table 3 Equations proposed for the conversion of the assessments *A* into scores *S* for the five components of the BASMI_{lin}

	<i>S</i> = 0 if:	Between 0 and 10:	<i>S</i> = 10 if:
Lateral lumbar flexion* (cm)	$A \geq 21.1$	$S = (21.1 - A)/2.1$	$A \leq 0.1$
Tragus-to-wall distance* (cm)	$A \leq 8$	$S = (4 - A)/3$	$A \geq 38$
Lumbar flexion (modified Schober) (cm)	$A \geq 7.4$	$S = (7.4 - A)/0.7$	$A \leq 0.4$
Intermalleolar distance (cm)	$A \geq 124.5$	$S = (124.5 - A)/10$	$A \leq 24.5$
Cervical rotation angle* (°)	$A \geq 89.3$	$S = (89.3 - A)/8.5$	$A \leq 4.3$

*For lateral lumbar flexion, tragus-to-wall distance, and cervical rotation the average of right and left should be taken.

If a score lies beyond the range 0–10, the values 0 or 10 have to be used, respectively. For facilitating computer calculations with “if ... then ... else” fields in a table calculation program such as Microsoft Excel, the limits of the linear ranges are also given. The BASMI_{lin} is the mean of the five scores.
BASMI, Bath Ankylosing Spondylitis Metrology Index.

Analysis

Descriptive statistics and Bland Altman analysis (showing the difference between two BASMI definitions per patient (y axis) plotted against the mean of two BASMI definitions per patient (x axis) were used to describe the absolute agreement across different BASMI definitions. Apart from showing the degree of agreement, Bland Altman plots give insight into whether both BASMI definitions behave similarly over the entire range of measurement or not.

The effect size according to Guyatt (mean change of TNF treated patients divided by the standard deviation of the change of the placebo treated patients) per BASMI definition was calculated for the patients in the trials to investigate differences in sensitivity to change.

RESULTS

Table 4 presents summary statistics for the various groups of patients for the BASMI₂, BASMI₁₀ and BASMI_{lin}. The entire range of possible scores is well represented in the various cohorts. Expectedly, the summary statistics of BASMI₁₀ closely resemble those of BASMI_{lin}. By contrast, the mean status score according to the BASMI₁₀ and BASMI_{lin} definitions are substantially higher as compared to the mean BASMI₂ score.

Figure 2 shows Bland Altman plots comparing the scores of the three BASMI definitions for individual patients. If two BASMI versions yielded exactly similar results, all data would lie along the x axis over the entire range of measurement. Comparing BASMI₁₀ and BASMI_{lin}, there are only small differences between the two scores and there is no clear pattern discernible along the range of measurement. By contrast, however, if the BASMI₂ is compared to either the BASMI₁₀ or the BASMI_{lin}, the BASMI₁₀ and BASMI_{lin} outweigh the BASMI₂ in the lower part of the range and undervalue the BASMI₂ in the higher part of the range (a heteroscedastic pattern).

Table 2 Conversion table for BASMI₁₀; the BASMI₁₀ is the mean of the five scores

If:	Then score =										
	0	1	2	3	4	5	6	7	8	9	10
Lateral lumbar flexion (cm)	≥20	18–20	15.9–17.9	13.8–15.8	11.7–13.7	9.6–11.6	7.5–9.5	5.4–7.4	3.3–5.3	1.2–3.2	≤ 1.2
Tragus-to-wall distance (cm)	≤ 10	10–12.9	13–15.9	16–18.9	19–21.9	22–24.9	25–27.9	28–30.9	31–33.9	34–36.9	≥37
Lumbar flexion (modified Schober) (cm)	≥7	6.4–7.0	5.7–6.3	5.0–5.6	4.3–4.9	3.6–4.2	2.9–3.5	2.2–2.8	1.5–2.1	0.8–1.4	≤ 0.7
Intermalleolar distance (cm)	≥120	110–119.9	100–109.9	90–99.9	80–89.9	70–79.9	60–69.9	50–59.9	40–49.9	30–39.9	≤ 30
Cervical rotation angle (°)	≥85	76.6–85	68.1–76.5	59.6–68	51.1–59.5	42.6–51	34.1–42.5	25.6–34	17.1–25.5	8.6–17	≤ 8.5

*For lateral lumbar flexion, tragus-to-wall distance, and cervical rotation the average of right and left should be taken.
BASMI, Bath Ankylosing Spondylitis Metrology Index.

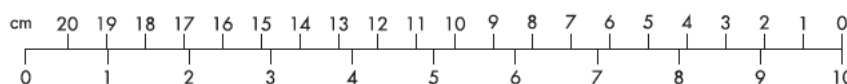
BASMI

Bath ankylosing spondylitis metrology index, a combined index to assess the spinal mobility in patients with ankylosing spondylitis

Name: _____

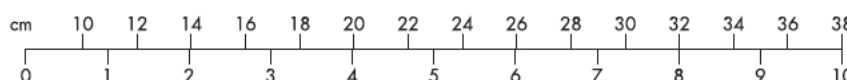
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- 1** Lateral lumbar flexion: patient stands with heels and buttocks touching the wall, knees straight, shoulders back, hands by the side. The patient is then asked to bend to the right side as far as possible without lifting the left foot/heel or flexing the right knee, and maintaining a straight posture with heels, buttocks, and shoulders against the wall. The distance from the third fingertip to the floor when patient bends to the side, is subtracted from the distance when patient stands upright. The manoeuvre is repeated on the left side.



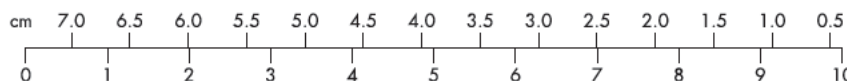
Mean of right/left

- 2** Tragus-to-wall distance: maintain same starting position as above. The distance between tragus of the ear and wall during maximal effort to draw the head back without raising the chin above its usually carrying level is measured on both sides to the nearest 0.1 cm, using a rigid ruler. Ensure no cervical extension, rotation, rotation, flexion or side flexion occurs.

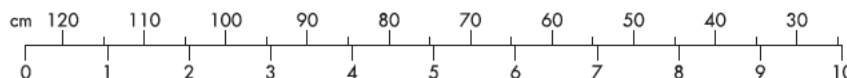


Mean of right/left

- 3** Lumbar flexion (modified schober): set marks in upright position at the level of the spinous process of L5 (found as the first process below the projected line across the back at the level of the top of the iliac crest) and 10 cm above the first mark. Measure distraction of the marks when the patient bends forward as far as possible, keeping the knees straight.

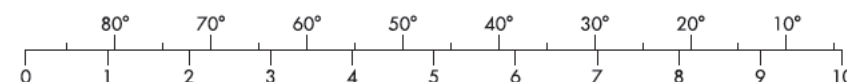


- 4** Intermalleolar distance: patient supine on the floor or a wide plinth, with the knees straight and the feet pointing straight up. Patient is asked to separate legs along the resting surface as far as possible. Distance between medial malleoli is measured.



- 5** Cervical rotation: patient supine on plinth, head in neutral position, forehead horizontal (if necessary head on pillow or foam block to allow this, must be documented for future reassessments). Gravity goniometer placed centrally on the forehead. Patient rotates head as far as possible, keeping shoulders still, ensure no neck flexion or side flexion occurs. Rotational angle to the right and to the left is measured.

If you do not have a gravity goniometer: patient sits with shoulders to the wall. Place goniometer to the wall above the patient's head. Patient rotates head as described above. Examiner aligns goniometer branch parallel to sagittal plane of the head.



Mean of right/left

BASMI:
(average
of 5 scores)

Figure 1 Scheme for the assessment of the Bath Ankylosing Spondylitis Metrology Index (BASMI) components and graphical conversion into BASMI_{lin} scores. Mark measuring results on upper scales, read corresponding score on lower scale. For the components 1, 2, and 5, the averages of right and left assessments have to be used. If a score would lie beyond the range of the scale 0–10, the values 0 or 10 have to be used, respectively.

Calculated Guyatt effect sizes were 0.66 for the BASMI₂, 0.95 for the BASMI₁₀, and 1.04 for the BASMI_{lin} respectively, demonstrating best sensitivity to change for the newly developed BASMI_{lin} definition.

DISCUSSION

The most important conclusion of this method comparison is that the different BASMI versions that have been defined

previously yield different BASMI scores if applied to the same patients. In particular the BASMI₂ performs fundamentally differently, which becomes clear if one interprets the Bland Altman plots. Summary statistics do not clearly show the problem, as the mean BASMI₂ is only slightly lower as compared to the BASMI₁₀ and BASMI_{lin} definitions. The Bland Altman plots comparing the BASMI₂ with both other BASMI definitions gives an immediate explanation: the classic

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Table 4 Summary statistics of the BASMI₂, BASMI₁₀, and BASMI_{lin} for the various patient groups used to evaluate the status scores and the change over a 24-week treatment period with either placebo or active treatment

	Patients (n)	Assessments (n)	Treatment	BASMI ₂	BASMI ₁₀	BASMI _{lin}
Status score OASIS	443	598	NA	3.6 (2.2) (0–10)/3 (2;5)	4.2 (1.7) (1–9.2)/4 (2.8;5.4)	4.1 (1.7) (0.5–9.2)/4.1 (2.8;5.3)
Baseline score trials	63	63	Placebo	4.3 (2.2) (0–9)/4 (3;6)	4.7 (2.2) (1–8.8)/4.8 (3.2;5.8)	4.8 (1.7) (1.2–9)/4.8 (3.3;5.9)
Baseline score trials	159	159	Active*	4.3 (2.2) (0–10)/4 (2;6)	4.7 (1.7) (1–9.2)/4.6 (3.6;6)	4.7 (1.6) (1.1–9.2)/4.6 (3.7;5.9)
Change score 24 weeks	63	63	Placebo	−0.14 (0.9) (−2–2)/0 (−1;0)	−0.19 (0.59) (−1.8–1)/−0.2 (−0.6;0.2)	−0.19 (0.54) (−1.68–0.88)/−0.17 (−0.54;0.16)
Change score 24 weeks	159	159	Active*	−0.59 (1.3) (−5–3)/−1 (−1;0)	−0.56 (0.9) (−4–2.6)/−0.6 (−1.2;0)	−0.56 (0.89) (−4–2.4)/−0.57 (−1.06;−0.32)

*One of the TNF blockers infliximab, adalimumab, or etanercept.

Data are presented as mean (SD) (range)/median (p25, p75).

BASMI, Bath Ankylosing Spondylitis Metrology Index; OASIS, Outcome in Ankylosing Spondylitis International Study; TNF, tumour necrosis factor.

BASMI₂ score is lower than the scores of the others if the BASMI is in the lower range, but higher if the BASMI is in the higher range, so that both differential effects extinguish each other, and the net effect on the grand mean is negligible. Such an effect can only be demonstrated in Bland Altman plots, as already suggested in the past by Bland and Altman, who argued that in method comparison one is interested in whether the difference between the measurements by the two methods is related to the magnitude of the measurement.¹¹ The explanation for this clear discrepancy is that the BASMI₂ does not behave as a linear measure, while the BASMI₁₀ and the BASMI_{lin} do. BASMI₂ is built on vaguely defined categories that may have a clinical implication but that also render the instrument inappropriate as a monitoring tool. The fundamental objection here is that a change of 1 unit in BASMI₂ has different meanings when the baseline BASMI value is 8 as compared to, eg, 5. The BASMI₁₀ and the BASMI_{lin} in particular show fewer floor effects, ie, are able to show changes in patients with limited restrictions. This can best be illustrated by the lateral lumbar flexion. If the lateral lumbar flexion is 10 cm or more this is always scored as 0 in the BASMI₂ where there are still five grades to differentiate between measurements over 10 cm in the BASMI₁₀ and the BASMI_{lin}. Similar effects are seen for the modified Schober where measurements above 4 cm always result in a score of 0 in the BASMI₂ while there are four grades available in the BASMI₁₀ and the BASMI_{lin}.

The results of this method comparison show that the proposed BASMI_{lin} definition, which is truly linear, closely resembles BASMI₁₀ scores. The small differences shown in fig 2C can be attributed to rounding errors associated with the categories in the BASMI₁₀ definition. This finding underpins the fact that BASMI₁₀ does not suffer so much from the metric limitations inherent to BASMI₂, and this makes BASMI₁₀ a more reliable instrument to use in monitoring spinal mobility over time than BASMI₂. Furthermore, the proposed BASMI_{lin} has a slightly better sensitivity to change as compared to the BASMI₁₀ version, which is undoubtedly due to the elimination of the categorical character of the latter. More importantly, with the linear equations presented in table 3 a computer evaluation in clinical trials, and putatively in clinical practice, is far easier to perform as compared to the conversion tables of the other two BASMI versions. Also, an evaluation by hand “at the bedside” is easy to perform if the form presented in fig 1 is used.

CONCLUSIONS

The BASMI₁₀ and BASMI_{lin} have clear and relevant advantages as compared to the BASMI₂. The main advantage of the new BASMI_{lin} over the BASMI₁₀ is its practicability in computer evaluations in clinical trials. It is important to realise that the BASMI₁₀ and BASMI₂ are not interchangeable. Which of the BASMI versions was applied should therefore be defined in

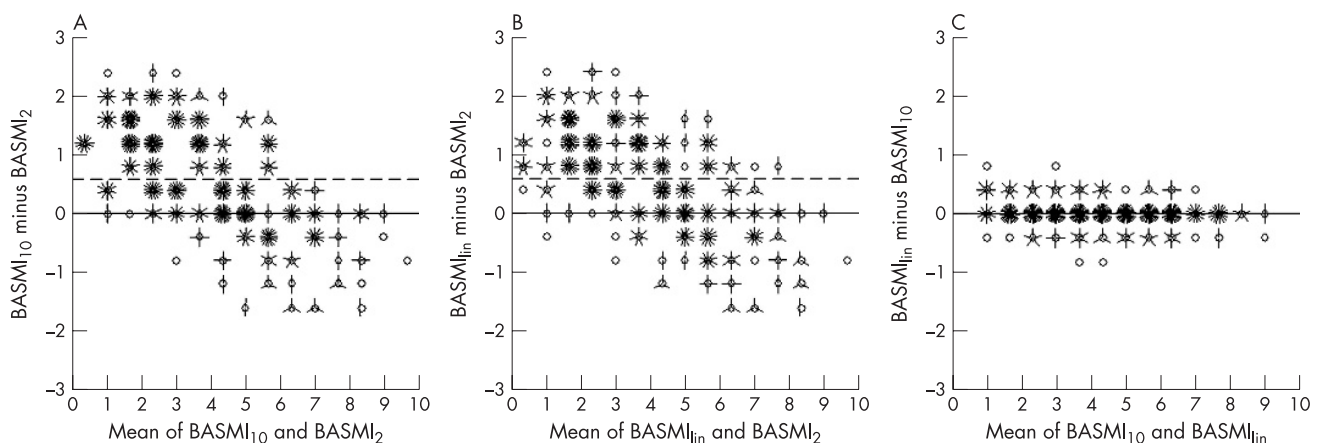


Figure 2 Bland–Altman plots comparing status scores of Bath Ankylosing Spondylitis Metrology Index (BASMI) versions. A. BASMI₁₀ with BASMI₂. B. BASMI_{lin} with BASMI₂. C. BASMI₁₀ with BASMI_{lin}. The y axis displays the difference between two BASMI versions per patient and the x axis the average of the two BASMI versions per patient. Each leaf of the flower represents one observation. The broken lines indicate the mean difference.

every publication in which spinal mobility is measured by using an index instead of separate measurements.

Competing interests: None.

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