Author's response to reviews

Title: Evaluation of the iPhone versus the Scoliometer for rib hump measurement in scoliosis

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Response to Reviewers Comments  
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We thank the reviewers for their thoughtful comments and suggestions on the journal paper submission. We have responded to each reviewer’s comments in detail below (reviewer comments are in italics and our responses are in plain text). The changes made in the paper as a result of the revisions are highlighted in yellow.

Reviewer #1 - Jeremy Fairbank:  This is nicely done paper, and I think it should be published by Scoliosis. I have no substantial criticisms. It would be of interest to submit these torsos to surface topography systems to investigate the relationship of the rib hump measurement to the output of these systems. Of course in real patients there is likely to a difference between the shape of the torso when standing erect and in the forward bending position.

No comments that require addressing for the current study. We agree that it would be interesting to consider a future surface topography characterisation of these plaster torsos, as such data could provide information on how well measurers select an ‘orientation of maximum rotation’ when positioning the scoliometer or smartphone for these measurements.

Reviewer #2 – Theodoros Grivas:  In this interesting article the authors present a novel use of plaster torsos as rib hump models for iPhone rib hump measurements, and they assess the inter- and intra-observer measurement variability using the iPhone and compare it to that of the Scoliometer. In their introduction the authors state a very inaccurate statement, which is “Axial vertebral rotation combined with rotary distortion within the spinal vertebrae is exhibited in the scoliosis patient by a twisting of the ribcage which is most easily visible when the patient is standing in the forward flexed position, known as the Adams forward bending test”. In the article the so called “twisting of the ribcage” is what is widely accepted as trunkal asymmetry and is something more than vertebral rotation and rotary distortion. It is termed angle of trunk inclination (ATI) or angle of trunk rotation (ATR). Trunkal asymmetry could be found in otherwise normal children with straight and not rotated spines, see Grivas TB, Vasiliadis ES, Polyzois VD, Mouzakis V. (2006). Trunk asymmetry and handedness in 8245 school children. DOI 10.1080/10428190500343027. Pediatr Rehabil. 2006 Jul-Sep;9(3):259-66 and Grivas TB, Daggas S, Polyzois BD, Samelis P (2002): The double rib contour sign (drcs) in lateral spinal radiographs. Aetiological implications for scoliosis? Stud Health Technol Inform, 2002: 88: 38-43. The question then is what exactly the scoliometer assess? The scoliometer reads and documents trunkal asymmetry and not scoliosis per se. It does not assess the deformity of the spinal column (the central axis), that is the scoliotic curve, which is traditionally assessed using the radiographs – (Cobb angle), even though in a number of publications the authors attempt to correlate these measurements, with the aim to reduce the exposure of the children to radiation. Scoliosis and trunkal asymmetry are not equivalent measurements, especially at a younger age, and it is now established that the surface asymmetry/deformity does not accurately predict the magnitude of scoliosis, especially in younger children.1 This is because, in younger children, trunkal surface and spinal asymmetry do not correlate statistically. The relationship of these two asymmetries becomes statistically significant in older children.1 This is additionally discussed below in connection to Amendt et al 1990 publication. 1. Grivas TB, Vasiliadis ES, Mihas C, Savvidou O. The effect of growth on the correlation between the spinal and rib cage deformity: implications on idiopathic scoliosis pathogenesis. Scoliosis 2007;14;2:11. 2. Grivas TB, Vasiliadis E, Mouzakis V, Mihas C, Koufopoulos G. Association between adolescent idiopathic scoliosis prevalence and age at menarche in different geographic latitudes. Scoliosis 2006;23:9. The accuracy (inter and intra reliability) of scoliometer, which is an instrument which assesses trunkal asymmetry - as described above, has previously reported. The method used for the reliability study and the results was reported in the article by Grivas TB, Vasiliadis ES, Polyzois VD, Mouzakis V. (2006). Trunk asymmetry and handedness in 8245 school children. DOI 10.1080/10428190500343027. Pediatr Rehabil. 2006 Jul-Sep;9(3):259-66. See Table III of this article. This article could also be included for the elaboration of the discussion of the reliability study.
The authors appreciate the comments being made by the reviewer regarding the complexity of the relationship between deformity of the vertebral column, and trunkal asymmetry. The term ‘twisting of the ribcage’ was used in the first sentence of the introduction as a general statement to imply that when the patient is positioned with the trunk flexed to the horizontal, the trunk is rotated (twisted) such that it forms an angle with the horizontal. This usage is consistent with the SRS glossary of terms definition of the Angle of Trunk Inclination (ATI). However, we acknowledge the uncertainties surrounding the link between trunkal asymmetry (as measured by ATI) and rotation of the vertebral column itself, and therefore we have attempted to improve the accuracy of the statement in paragraph 1 by rewording the sentence as, “Axial vertebral rotation combined with rotary distortion within the spinal vertebrae contribute to the overall trunkal asymmetry found in the scoliosis patient which is most easily visible when the patient is standing in the forward flexed position, known as the Adams forward bending test.”

Respectfully, we do not wish to include a detailed discussion of the extent to which trunkal asymmetry (as measured by the scoliometer) reflects underlying vertebral rotation, since the intention of the paper was to compare two methods of measurement for this widely used clinical assessment test. The authors at no point in the paper made comment or attempted to correlate trunkal asymmetry with spinal deformity/scoliosis measures as this was not the purpose of this paper. The extent to which trunkal asymmetry should or should not be relied on clinically (especially in younger patients as the reviewer points out) is a valid and important question, but is beyond the scope of this study. However as suggested by the reviewer, the reference related to previous reliability studies of the Scoliometer (Grivas et al, Pediatr Rehabil 2006) will be included in the references list of the paper because it is directly relevant to the question of scoliometer reliability (refer to the first sentence of paragraph 2) and references adjusted accordingly.

In discussion section, the authors state that “As with the Bunnell Scoliometer, the iPhone together with the Scoligauge software application is a simple, inexpensive and portable method of measuring rib hump progression and a practical way to decrease exposure to radiation from repeated radiographs [3,4,11]”. It would be useful to comment on the limitations of this statement, using what is reported by Amendt et al 1990. They write that the Scoliometer measurements made by two raters on 65 persons with idiopathic scoliosis were correlated with radiographic agreement of vertebral (pedicle) rotation and lateral curvature (Cobb method). Correlations ranged from .32 to .46 with pedicle rotation and from .46 to .54 with the Cobb angle. Frequency analysis revealed relatively good specificity, sensitivity, and predictive capability of the Scoliometer. Intrarater and interrater reliability coefficients were high (r = .86-.97). These results indicate good measurement reproducibility. The less than optimal between method correlation coefficients suggest that the validity of Scoliometer measurements is not sufficient to use this method alone for determining patient diagnosis and management. Based on the positive-frequency analysis however, the use of this tool as a screening device would be appropriate. Amendt LE, Ause-Ellias KL, Eybers JL, Wadsworth CT, Nielsen DH, Weinstein SL. Validity and reliability testing of the scoliometer. Physical Therapy 1990;70:108–117. These findings can be accepted especially if we consider some new knowledge based on the recent published research on the correlation of surface (trunkal) and axial (spinal) deformity, by Grivas et al 2007, which was also discussed above; Grivas TB, Vasiliadis ES, Mihas C and Savvidou O (2007): The effect of growth on the correlation between the spinal and rib cage deformity: implications on idiopathic scoliosis pathogenesis. Scoliosis 2007, 2:11 doi:10.1186/1748-7161-2-11. We think that it is important to emphasize again that this research documented that growth has a significant effect in the correlation between the thoracic and the spinal deformity in girls with idiopathic scoliosis. In younger children the concordance of the surface and spinal deformity is weak and it becomes stronger as the children are growing up. Therefore, in younger children with surface/trunk asymmetry, the prediction of the spinal deformity alone from the surface topography is inaccurate. Consequently this knowledge should be taken into consideration when trying to assess the spinal deformity from surface measurements and correlate surface and radiological readings. Huang 1988 also reported on the effectiveness of this instrument but he studied the correlation of scoliometer with radiographical readings. Based on his findings of this correlation he concluded that the value of the scoliometer in school scoliosis screening still needs further evaluation, a statement that according to our opinion underestimates the value of the Scoliometer for screening asymmetry and is not acceptable. The age range of screened children by Huang et al was 12 – 14 years old. As we previously discussed in this age range of screened children the correlation of surface and radiographical deformity is not statistically
significant, therefore the author’s findings were expected and predicted. Huang SC: Effectiveness of scoliometer in school screening for scoliosis. Taiwan I Hsueh Hui Tsa Chih 87:955-959, 1988 J Formosan Med Assoc 1988; 87:955-959.

Again we emphasise that the aim of this study was not to investigate the relationship between trunkal asymmetry (as measured by the scoliometer) and spinal deformity, because our study does not include measures of spinal deformity for these patients. The aim of the study is solely to determine the extent to which rib hump measurements made using the inclination measuring tool on the smartphone are equivalent to those made using the traditional scoliometer. Since we are not measuring spinal deformity in this study, it would be inappropriate of us to make any comment on how the trunkal asymmetry measures performed in the paper relate to spinal deformity measures. However, we have added a comment in the Discussion to make readers aware that previous work by the reviewer has investigated this question of the correlation between trunkal asymmetry and spinal deformity, and specifically to highlight the point that trunkal asymmetry should not be considered as a definitive measure of spinal deformity “Although the correlation between trunkal asymmetry and vertebral column deformity is beyond the scope of this paper, it is important to recognise that when considering the correlation between trunk asymmetry measures and spinal deformity, previous work by Grivas et al 2007 found that in children aged 7-13 years the concordance between trunk and spinal deformity was weak but became stronger for children aged 14-18 years. It should also be noted that trunkal asymmetry measurements alone are not sufficient for determining a definitive patient diagnosis and management plan. (Ref Amendt et al 1990)”


All avenues were exhausted trying to locate this journal/paper during the writing of the initial submission to Scoliosis. Considering the reference is almost 30 years old and we were unable to locate a copy, we did not wish to include it without knowledge of the contents. We note that References 3-7 of the paper provide more recent scoliometer reliability studies (1990-2010), and that the reference list was not intended to be exhaustive.

Finally one possible limitation of the introduced torso model is that the examiner could not easily palpate-recognize the spinous processes on it, as he/she can easily do “in vivo”, making the measurements inaccurate.

When the study was designed we also considered this issue but as you can see clearly in both Figures 1 and 2 the spinous processes are clearly visible on the plaster models despite the overlaid foam layer. The spinous processes can still be ‘palpated’ through the overlaid foam layer.

Reviewer #3 – Carl-Eric Aubin: This paper presents an evaluation of two techniques to measure the rib hump angle; the Scoliguage application and an iPhone with an acrylic sleeve and the standard Scoliometer. The subject of this paper is of great interest considering the growing interest and accessibility of applications now available on smart phones. This is a very straightforward paper which is quite well written. The methodology is detailed and thorough. It is suggested to add details on the patient data used to generate the plaster torsos (i.e. type of scoliosis, Cobb angles, axial rotation at the thoracic apical vertebra, etc.)

We chose not to include patient-by-patient information on the deformities because the aim of the study was only to measure rib humps using the two assessment tools to compare their performance. With regard to the question of trunk rotation however, we stated in the first paragraph of the results that the mean rib hump for the group was 16°, with a range of 6-30°, therefore the plaster torsos cover quite a large range of trunkal asymmetries, representative of those which would be encountered in clinical practice. We have added a sentence to this effect in the Discussion, end of Paragraph 1. With reference to the apical vertebral rotation (and consistent with our response to the previous reviewer) we are unable to comment on this as our study did not include radiographic measures of vertebral column rotation for the patient on whom the plaster torsos were based.
The study is well performed. My only criticism of the overall approach is the fact that the plastic rib hump eliminates the variability normally seen in patients during the measurement of the rib hump (posture, position of forward bending, etc.), which could possibly be more important than the accuracy of the devices. It could have been interesting to combine the study with measurements of real scoliotic subjects using the two techniques to compare measurements in ‘real’ situations, as well as to document intra- and inter-measurer repeatability of real cases. If two measurements of the same patient are taken consecutively, measurement of the rib hump will vary - sometimes considerably. With such a 'moving target' to be measured, just how accurate does the measurement need to be? (It appears that both techniques are accurate enough). Such complementary approach and required accuracy should at minimum be discussed.

This insight is exactly why we designed the study to eliminate patient positioning variability – to the best of our knowledge there have been no previous attempts to separate patient positioning variability (i.e. the object being measured) from the ‘inherent’ measurement variability of the measuring tools and observers. Therefore because our stated aim was to compare the use of two measurement tools, it was appropriate for us to remove the patient positioning variability.

It may well turn out to be true that patient positioning variability is equivalent to, or greater than inherent measurement variability for the scoliometer/iPhone, but we first needed to establish what the inherent measurement variability was, and this is what we have done in this study. It would now be an interesting future study to characterise the magnitude of patient positioning variability compared to the ‘inherent’ measurement variability reported here, but this is a separate question to that of equivalence between two measurement tools. For clarity the following sentence will be added to the conclusion, “We note that using the iPhone in the clinical setting to measure trunkal asymmetry is subject to patient-positioning variability, and this variability is an unavoidable clinical factor which will occur regardless of the chosen measurement device used.”

Also, the title should reflect that the iPhone was not used alone, but with an acrylic sleeve (it is well stated in the Conclusion, but not in the title). As measurements were not reported with the iPhone alone, the current title may be misleading.

Thank you for your suggestion. The title will be changed to, “Evaluation of the iPhone with an acrylic sleeve versus the Scoliometer for rib hump measurement in scoliosis”