Editor

Dear Authors,

The article is well written and the methodology is sound, the topic is innovative and interesting. Congratulations for the paper, with few improvements the article will be ready to be published. Please answer to all the reviewers’ comments, I have only one more comment, please try to focus the discussion on the clinical impact of the tested device.

Authors’ response

Thanks. We hope that the refocused elements of the discussion address your comment:

(page 20, line 20)

“While different types of back pain may result in different patterns of movement or movement restrictions, it is not clear how this would change the average concurrent validity of the device for measuring inclination in the cardinal planes tested. Therefore, our study’s results may generalise to the broad low back pain population. However, suitably designed and powered studies would be required to test this definitively, especially for more complex 3D movement.”

(page 21, line 8)
“Clearly, the relatively low cost of wireless motion sensors compared to laboratory systems, and their ability to assess movement and provide individualised biofeedback in patients’ activities of daily living, are all advances that hold potential promise for innovations in the management of musculoskeletal disorders. However, exploration and validation of the clinical potential and limitations of this technology are a multi-stage and incremental process. The quantification of concurrent validity for measuring cardinal plane inclination using one type of motion sensor device is only a very early step in that process.”

Reviewer 1

This manuscript describes a study investigating the concurrent validity of a wireless motion sensor system (ViMove) compared to an optoelectronic motion capture system (Vicon) in measuring lumbar angles during sagittal and coronal plane range of motion movements. Overall, the manuscript is very well-written and relatively clear. Below are comments and suggestions for the authors to consider in their revisions.

Authors’ response

Thanks.

Reviewer 1

Methods

1) Page 8, Lines 13-14: Please clarify that the movements were performed to end range (which seems to be the case).

Authors’ response

We have amended this sentence by adding “… to their comfortable end of range”:

(page 9, line 13)

“The neutral lumbar position for each participant was initially recorded by both systems while the participant was asked to stand still for 5 seconds in his/her usual standing position, and then perform three repetitions each of flexion, extension, right lateral flexion and left lateral flexion to their comfortable end of range.”

Reviewer 1

2) Page 9, Line 7: Please state the resolution of the cameras that were used.

Authors’ response
We have now detailed this:

(page 10, line 8)

“The Vicon system consisted of 8 MX-T20 (2 megapixel), 8 MX-T40 (4 megapixel) and 2 Bonita digital high speed cameras (1 megapixel), which were driven by Nexus software (version 1.8.5) at a sampling rate of 200 Hz (Vicon Motion Systems Inc, Los Angeles, CA, USA).”

Reviewer 1

3) Page 9, Line 19: Please clarify what is meant by “body language script” (e.g., Vicon BodyBuilder software).

Authors’ response

Yes, that must have been confusing. We have changed this sentence to:

(page 10, line 20)

“The angles were extracted from Nexus using a software script written in the program ‘Vicon BodyBuilder’.”

Reviewer 1

Discussion

1) The term “through range” is used in several places throughout the Discussion. To avoid confusion, it is suggested that this term be replaced with “motion through a full range” (or something similar).

Authors’ response

We now define this term in the method section:

(page 13, line 18)

“As we analysed concurrent validity through the full range of movement, we use the term ‘through range’ to contrast the findings with studies that only assessed concurrent validity at end of range.”
2) The first paragraph on Page 15 suggests that certain RMSE and LOA values are deemed “acceptable”. It would be helpful to clarify that caution should be used when applying these values to movements/tasks in which the range of motion in a particular direction is within the range of calculated error/limits.

Authors’ response

Concurrent validity quantifies the differences between measurements from two systems. In this case, the Vicon system is a not gold standard (as it has its own measurement imprecision) and therefore the differences cannot be deemed to be error in the ViMove system. The RMSE and LOA quantify differences between measurements, in this case through the entire available range of movement. As noted by the American Medical Association’s guide to measuring spinal range of motion, a 5 degree difference is deemed acceptable. So, as our RMSE and LOAs were below 5 degrees, we considered the concurrent validity to be acceptable.

However, after considering your comment, we recognize that clinicians need some practical way to interpret the LOA and have added this sentence:

(page 16, line 10)

“Our results indicate that caution should be used when attempting to infer that inclination angles measured using ViMove that are smaller than the LOA, would be the same when measured using Vicon, or vice-versa. Absolute inclination angles smaller than the LOA may be measurement error, although we cannot know from this study the sources of that error and whether they resulted from the ViMove or ViCon systems.”

Reviewer 1

Conclusion

The statement that the motion sensor system “can be used with greater confidence… to provide knowledge of an individual’s movement behaviour in daily activities” is not supported by the results of the study. This is pointed out in the previous section (Page 19, Lines 8-10). Please edit this sentence to better reflect the scope and limitations of the study.

Authors’ response

We have edited these sentences to:

(page 21, line 19)

“This evidence of the ViMove system providing valid measurements of lumbar inclination means that it can be used with greater confidence to assess an individual’s single plane lumbar inclination in clinical situations and in daily activities. Further research is required to evaluate
the system’s ability to measure complex functional movements and intersegmental spinal kinematics.”

Reviewer 1

Additional Points

1) The motion capture markers are described as “reflex markers” in several places throughout the manuscript. It is suggested that the word “reflex” be removed in each instance, and the markers be described as “surface markers” or simply “markers”.

Authors’ response

We now use the term ‘surface markers’ throughout the manuscript.

Reviewer 1

2) There are several instances in which it is suggested that “lumbar spine kinematic motion” (or “spinal kinematics”) were not being measured during the study. This is misleading since kinematic variables (i.e., segment angles) were calculated. The limitations section further states that measuring “lumbar spine kinematic motion” requires video fluoroscopy or functional MRI. This suggests that the authors are referring to intersegmental spinal motion. It is suggested that the terms “lumbar spine kinematic motion” and “spinal kinematics” be replaced with a more appropriate term throughout the manuscript.

Authors’ response

Yes, in hindsight this language did lack precision. We have amended these sections:

(page 6, line 3)

“We compared their capacity for measuring lumbar region surface movement, rather than lumbar spine intersegmental motion, because that is what clinicians routinely assess in the clinic. Although it is often believed that treatment interventions for LBP specifically affect symptomatic structures in the lumbar spine, treatment decisions in clinical practice are based on movement patterns (lumbar region motion) visually observed by the clinician, rather than intersegmental spinal kinematics. An additional consideration in choosing this method was the absence of a validated Vicon kinematic model for intersegmental movement of the lumbar spine.”

(page 19, line 16)

“However, this does not provide any data on the validity of ViMove sensor measurements being representative of intersegmental lumbar spine kinematic motion, as that would require a different study design and measurement methods, such as comparison with video fluoroscopy or
functional MRI. When measuring lumbar region kinematics with surface-based measurement systems, some measurement error is to be expected, due to movement of skin and superficial tissues as well as the clinician’s ability to identify anatomical landmarks in a reliable and valid way [3].”

(page 21, line 23)

“Further research is required to evaluate the system’s ability to measure complex functional movements and inter-segmental spinal kinematics.”

Reviewer 1

3) Figure Legends:

Authors’ response

Sorry but it was not clear whether a comment was missing here or whether this item should have been removed.

Reviewer 1

4) Page 5, Line 11: Change “measure” to “measuring”.

Authors’ response

Thanks, we have corrected this.

Reviewer 1

5) Page 18, Line 20: Change “20Hx” to “20 Hz”.

Authors’ response

Thanks, we have corrected this also.

Reviewer 2

I would like to acknowledge the authors for writing a nice paper. I have a few questions and comments, that I hope the authors will consider.

Authors’ response
Thanks.

Reviewer 2

Introduction

Overall, when I read the introduction I was waiting for results that indicated differences between those with pain compared to those without pain, since part of the introduction is used to describe that there are differences in movement characteristics. I do understand why you emphasise this in the introduction and also why you were not able to investigate this. I think maybe if you refine the aim of the study by also including a short description of the study population it will make this more clear.

Authors’ response

We emphasize this in the introduction to underline that movement characteristics may be important in people with LBP and therefore tools that accurately measure these characteristics might be useful.

However, as we are not aware of robust arguments about why the concurrent validity would differ between the populations of people with pain and those without (due to their considerable overlap), we used a mixed sample to enable a broader generalizability. Therefore, as investigating differences in the concurrent validity of the device between these two sub-populations was not an aim of the study, it was not adequately powered to do so. We have added this to the aim of the study:

(page 6, line 12)

“While there are some differences between the lumbar movement patterns of people with and without pain, there is also considerable overlap between these populations [2], and as we were not aware of any a priori reasons for why the average concurrent validity might differ between these populations, we recruited participants with and without LBP to ensure a mixed study sample with diverse movement patterns. We also chose to test people rather than testing movements generated by artificial/robotic equipment because people’s spines can move in unpredictable ways.”

Reviewer 2

Methods:

Did you have some overall inclusion criteria for the participants? For instance when you recruited the study participants did you aim for a certain number of people with pain and a number of people without pain?
We have added this paragraph:

(page 7, line 9)

“LBP was defined as pain between the lower costal margins and above the inferior gluteal folds (Dionne et al., 2008). Participants with LBP had to have current or recurrent LBP. Current LBP was arbitrarily defined as experiencing an average pain of >2 on a 0-10 Numeric pain Rating Scale (NRS) over the past 3 weeks. Recurrent LBP was defined as “LBP which has occurred at least 2 times over the past year with each episode of LBP lasting at least 24 hours, with a pain intensity of >2 on an 11-point NRS ….. and with at least a 30-day pain-free period between episodes” (Stanton et al., 2011). Participants with no LBP could not have (i) experienced an episode of LBP during the past year lasting >24 hours with pain intensity self-reported as >2 on an NRS, or (ii) LBP during the past 3 weeks, or (iii) been currently seeking care for LBP. All participants had to be >18 years old and able to read and communicate in Danish.”

Reviewer 2

page 6 line 15-18: these sentences are difficult to understand, I suggest you rephrase them.

Authors’ response

As detailed above, we moved these sentences to the end of the introduction section and hope they are clearer in this amended form:

(page 6, line 12)

“While there are some differences between the lumbar movement patterns of people with and without pain, there is also considerable overlap between these populations [2], and as we were not aware of any a priori reasons for why the average concurrent validity might differ between these populations, we recruited participants with and without LBP to ensure a mixed study sample with diverse movement patterns. We also chose to test people rather than testing movements generated by artificial/robotic equipment because people’s spines can move in unpredictable ways.”

Reviewer 2

Sometimes you name the population as a cohort and other times they are mentioned as participants. I would probably choose participants or study population and not cohort.

Authors’ response

Wherever ‘cohort’ had been used, ‘study population’ is now used.
Reviewer 2

In the test procedures (page 7 line 9-10) it would be nice with a little more description of the questionnaires, e.g. that you measured LBP characteristics with Roland Morris and also provide a reference.

Authors’ response

We had added this sentence:

(page 8, line 8)

“To provide descriptive information about the study population, participants’ height and weight were measured and they self-completed a demographic questions pack that included their general demographic attributes, and any LBP-related characteristics, including the Roland Morris Disability Questionnaire [16] (23-item version) and Numeric pain Rating Scale [15] (0 to 10 scale).”

Reviewer 2

Results

What is your definition of LBP?

Authors’ response

As now described above, it was:

(page 7, line 9)

“LBP was defined as pain between the lower costal margins and above the inferior gluteal folds (Dionne et al., 2008). Participants with LBP had to have current or recurrent LBP. Current LBP was arbitrarily defined as experiencing an average pain of >2 on a 0-10 Numeric pain Rating Scale (NRS) over the past 3 weeks. Recurrent LBP was defined as “LBP which has occurred at least 2 times over the past year with each episode of LBP lasting at least 24 hours, with a pain intensity of >2 on an 11-point NRS ….. and with at least a 30-day pain-free period between episodes” (Stanton et al., 2011).”

Reviewer 2

Discussion
I suggest that part of the discussion in shortened. For instance, the comparison to other studies could be shortened, e.g. from line 12 on page 15, the description of previous studies could be shorter.

Authors’ response

We have shortened this section, while retaining the components we believe are required to highlight the differences between studies and the potential clinical implications of those differences.

Reviewer 2

Conclusion

I find that there are some things in the conclusion that needs to be considered. On page 19 line 8-9 you mention that the system's use with respect to measuring complex functional movements has not been done. But in the conclusion, you conclude that the system can be used to measure an individual's movement behaviour in daily activities. I think that these two statements somewhat contradict each other. So, I would be a bit more careful in the conclusion.

Authors’ response

We have amended this to:

(page 21, line 19)

“This evidence of the ViMove system providing valid measurements of lumbar inclination means that it can be used with greater confidence to assess an individual’s single plane lumbar inclination in clinical situations and in daily activities. Further research is required to evaluate the system’s ability to measure complex functional movements and inter-segmental spinal kinematics.”

Reviewer 3

Congratulations to the authors for the interesting paper. I have few comments to improve the paper:

Authors’ response

Thanks.

Reviewer 3
1) in the abstract, section "Conclusion" you started this section with a sentence which pertains to the method section. Please in this section simply summarize the final conclusion of the research.

Authors’ response

In this sentence, we had tried to provide an overall summary of the findings and our interpretation of their meaning. It has now been amended to:

(page 3, line 5)

“We found clinically acceptable level of agreement between these two methods for measuring standing lumbar inclination motion in these two cardinal movement planes.”

Reviewer 3

I suggest to enrich the discussion with some comments about the chosen population: do you think that the selected sample is generalizable to the low back pain population? Do you think that this device is able to detect smaller ranges of motion in people with a stiff spine and low back pain?

Authors’ response

We have now expanded on this:

(page 20, line 20)

“While different types of back pain may result in different patterns of movement or movement restrictions, it is not clear how this would change the average concurrent validity of the device for measuring inclination in the cardinal planes tested. Therefore, our study’s results may generalise to the broad low back pain population. However, suitably designed and powered studies would be required to test this definitively, especially for more complex 3D movement.”

Reviewer 3

You compare the Vimove system to another measurement system, which can be more popular, or more used, but how can you define it as a standard measurement? We are talking about new instruments, I would not talk about standard because I think that in this field and regarding these new kind of measurements a standard is far from being defined.

Authors’ response

We use the word ‘standard’ in the context of a ‘reference standard’ for calculating concurrent validity. That process requires a comparison between the data from an ‘index’ test or instrument and the data from a ‘reference standard’ test or instrument. In this case, we chose Vicon as the
reference standard because it is a common biomechanical tool that has been extensively validated but, as you point out, there are other tools that could have been chosen as the reference standard.

In case it is useful, we have deleted ‘standard’ from the following sentence:

(page 18, line 19)

‘In addition, the movements that are typically tested in the clinic were measured and compared with a reference method considered accurate for surface measurements of human motion’