Author's response to reviews

Title: A novel magnet based 3D printed marker wand as basis for repeated in-shoe multi segment foot analysis: a proof of concept

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Reviewer’s comments

Reviewer #1:

The authors present a magnetic two-part marker system designed to help measure in-shoe multi-segment kinematics. The reliability of replacing the makers was tested in static and walking trials and found to be good. I do think using magnets for the wand is a nice idea, but I'm just not convinced that the authors have provided enough justification here to warrant a full manuscript. Other screw-based detachable markers with low profile bases already exist, both custom made by researchers and commercially available.

M.E.:

We commend the reviewer for his review and constructive feedback.

While preparing the current manuscript, we intended of submitting this study as a technical note or short communication. However, when checking for possible submission types for this particular journal, we believed that a ‘research article’ was best suited.

We agree with the argument raised concerning other detachable markers. However, since we plan to use these markers in future projects where multiple shod conditions need to be tested
during one session, estimating the reliability of detaching the wand of and placing them back on again was important. Where screw-based markers took plenty of time, these magnet-based wand decrease test duration.

Major revisions:

R1 - comment1: It's important to note that the benefits of this marker are for within session testing, and that for multiple sessions where the base elements need to be removed and replaced reliability remains a significant problem for multi-segment foot research.

Response comment 1 - Reviewer 1:

We strongly agree with this statement. We found it also very important that the reader understands that these novel markers are designed for the purpose to assess repeated in-shoe measurements during one session and therefore chose to emphasize this statement by adding this to the title of the paper. Furthermore, we opted to not include inter-rater reliability measurements, since the main function of these new markers was not to solve reliability issues in barefoot multi-segment foot measurements.

R1 – comment 2: Only walking trials were tested. In running and sports movement trials the forces are much greater, are the magnets able to hold reliably during these types of activities?

Response comment 2 - reviewer 1:

A good point was raised here as reliability of the robustness of the magnet-based link may vary during running trials. We did not include running trials in our paper since our research group did not have the intention of capturing running trials with these markers in the near future. However, when using these markers later on in running studies, reliability indeed has to be re-assessed during running and sports trials.

The force of magnets was estimated at 7,4 N by the engineer involved in this study. Adding the extra support of 5 holes in the baseplate, we do believe that these markers will also hold during running trials.

If needed, we are able to add technical sheets to enlighten the technical information of the magnets.

We adjusted the discussion and added a sentence involving this comment (line 180 – 183). (Highlighted in green).

“Last, additional research will be necessary to gain confidence for use in a clinical population and also in settings where running trials need to be captured, since forces on the foot will be greater and reliability of the robustness of the magnet-based link needs to be re-evaluated.”
R1 – comment 3: Lines 93-98: Using a reference marker here to account for foot movement assumes that the foot and ankle are a rigid body, this is not correct.

Respons comment 3 - reviewer 1:

We strongly agree with this comment and added a statement of limitation to current study. We are aware that this is not completely correct, however, we think a certain coupling pattern is present between these two anatomical entities. As the lateral malleolus marker was nearest to the novel markers and remained fixed on the subject during the whole measurement protocol, we used this as a reference to keep it as correct as possible. Also, placing another reference marker closer to the foot was impossible to standardize and we were also unable to do this due to logistical circumstances.

This was adjusted in the manuscript and highlighted in green. (line 173-176).

“The reference marker used to account for foot movement is not ideal, since this would imply that ankle and foot are rigid. Yet, we were not able to add another reference marker onto the foot, since this was impossible to standardize in this type of measurement.”

R1 – comment 4: A more thorough discussion is required placing these results in the context of the existing literature. In theory, because of the design of the markers, the variation seen between sessions where the markers have been replaced should be very close to that measured during walking trials without the markers replaced, is this the case?

Respons comment 4 - reviewer 1:

We added some extra thorough information in the discussion paragraph and hope this suffice for the reviewer (highlighted in green, line 154-158 and 160-162). Results of the intra- and inter variability data indeed demonstrate a very close variation of kinematics between session and within sessions, as was described in the discussion.

“This demonstrates the advantage of the magnet fitting principle, which insures near to identical positions of the marker wand, even when they ought to be taken on and off their baseplates. Also, changing shoes will not alter the baseplate position, which initially was considered as a risk since some of the baseplates are located on protrudes anatomical entities. Reliability of measuring similar in-shoe foot kinematics in a repeated-measurements design tended to be very high as suggested by the ICC outcomes. Looking at existing research regarding reliability of regular markers, these novel markers score higher on average as suggested by ICC outcomes compared to these other studies”

R1 – comment 5: I much prefer Bland-Altman plots to be included in reliability studies as this is a simple and intuitive way for the reader to assess the reliability of the data compared to dimensionless ICCs.

Respons comment 5 - reviewer 1:
We very much appreciate this proposal and reconsidered using the Bland-Altman plot. However, we believe that this plot is very useful in assessing agreement between different measurement methods and therefore decided that it was not applicable for current study.

Bland-Altman plots however can be applicable on the results in this paper by comparing one marker placement relative to another, but this implies plotting a plethora of variables and measurements and thus would be uncluttered.

We hope the reviewer agrees with this statement.

Minor revisions

R1 – comment 6: Having broken a number of markers in my time, I imagine another advantage of this set up is that the marker and wand can be knocked off during gait without damaging the wand?

Respons comment 6 - reviewer 1:

We agree with this statement. We did a lot of considerations with respect to the ideal length of the wand. They had to be long enough so cameras would be able to detect them throughout the shoes, but also short enough so normal gait would be possible without knocking of medially located wands during walking.

Up to date, we already used these markers plenty of times in our lab and so far none was damaged.

R1 – comment 7: Line 49-62: Are there plans to make the design of the marker system freely available to the research community (i.e. CAD files for printing)? And what are the cost of the marker system compared to standard devices?

Respons comment 7 - reviewer 1:

We indeed have the intention of making the design freely available for research purposes only. Therefore, we will directly communicate with research groups who are interested in the design and we will personally send the necessary CAD files for printing.

We did not generate a cost-effectiveness study. Yet, in our own experience, when comparing to the regular markers used in our clinical motion laboratory, the costs of these novel markers are 300% less than regular marker costs. (Ca. 2 euros compared to ca. 6 euros respectively per marker)

R1 – comment 8: Line 132: Typo: "whit"

Respons comment 8 - reviewer 1:

Adjusted in manuscript: line 143
Reviewer #2:

Thank you for the opportunity to review this article. The development and initial testing of the reliability of a new marker for testing foot kinematics is very promising indeed. The following are suggestions for the article.

M.E.: We commend the reviewer for his review and constructive feedback.

Abstract

- Background

R2 - comment 1: The first sentence is slightly confusing. Not sure if the application of in-shoe multi segment foot kinematic assessment has faced challenges in the past or is currently facing challenges. Could you make a minor amendment to make this clear.

Respons comment 1- reviewer 2:

We understand possible confusing and adjusted the sentence to make it clearer.

Adjustment: line 2

- Results

R2 - comment 2: Can you include the kinematic variables that were the source of the values that you state. Without context it is difficult to ascertain what these results mean.

Respons comment 2: We agree with this statement and adjusted the abstract. Yet, we added the kinematic variables used in the study in the method section.

Adjustment: line 9-10

“Multi-segment foot kinematics of ten participants were recorded and kinematics of hindfoot, midfoot and forefoot were calculated.”

Background

R2 - comment 3: Line 21. Missing a word - 'in the last ten years'

Respons comment 3:

Adjustment: line 21
R2 - comment 4: Line 26 - can you please define the difficulty to apply regular markers. Is it because you cannot easily access the skin directly?

Respons comment 4:

Adjustment: line 26-27

“the difficulty to apply regular markers due to the fact that the skin is not directly accessible,”

R2 - comment 5: Line 29 - Can you please explain how shoes were modified. Was it by cutting windows to allow access for markers

Respons comment 5:

The shoes discussed in this line were modified by the research groups conducting the articles that were referred to (reference 6-10). Since not all modifications were alike (for example: cutting windows, adding upper webs, and so on.. ), we chose not to explain in detail all of the modifications, as this would be to broad and not directly linked to the general aim of this study. We hope the reviewer agrees with this comment.

R2 - comment 6: Line 38 - missing a word? 'the current study'

Respons comment 6:

Adjustment: line 38

R2 - comment 7: Line 34 - The aim of the study is not absolutely clear, as there was no mention of assessing reliability of the new markers. Can you please make it explicit what the aim of the study was in relation to the new markers?

Respons comment 7:

We firmly agree with this comment and added more information regarding the aim of current paper to make it more explicit.

Adjustment: line 39

“The objective of the current study was to develop and assess reliability and repeatability of a thin and solid in-shoe marker wand, consisting of a baseplate and marker-unit, with user-friendly features that allow for repeated in-shoe multi-segment foot analyses using modified shoes.”

Methods
R2 - comment 8: Line 60. Presumably the usefulness of the new marker is dependent on the strength of the magnets. You provide values for magnetic force but can you please provide some context as to how this strength can withstand force that may be applied during gait

Respons comment 8:

Adjustment: line 62-65

“Since accelerations during walking remain low, orthogonal forces applied onto the magnets are inferior to the magnet forces, causing that the marker wands stay fixated into their baseplates throughout measurements.”

R2 - comment 9: line 62 - Can you please provide more details about the material used to construct the rod.

Respons comment 9:

Adjustment: line 66-68

“this material has a tensile strength of 50-65 MPa, a polymerized density of 1.17 g/cm³ and flexural strength of 110 MPa, which compared to other commonly used materials is high.”

We hope this suffices for the reviewer.

R2 - comment 10: line 78 - Can you please explain how the baseplates were fixated to the skin.

Respons comment 10:

Adjustment: line 86-87

“these were fixated onto the skin using double-sided tape (Scotch® 19mm Double Sided, 3M, Minnesota, US).”

R2 - comment 11: Line 78 - The method for testing the markers is confusing. Ultimately the base plate is applied and remains in situ for the duration of the testing session while the reliability of kinematic variables was assessed after removing and reapplying the rod to the baseplate. Can you please make this clear?

Respons comment 11:

We hope to have improved clarity on this method as this was adjusted in the manuscript: Line 83-86

“First, 5 static trials were captured in sitting position while baseplates were applied and remained in situ for the duration of the testing session. In between the 5 static trials, the therapist removed
and reapplied the rod to the baseplates to assess repeatability and robustness of the magnet fitting.”

R2 - comment 12: line 88 - Can you please provide some more information about the amount of time that the trial was conducted. 'Up to 3 times' does not make this clear.

Respons comment 12:

Adjusted in manuscript: Line 97-99.

“This process was repeated up to three times so that a total of 9 trials were captured with replacing of the marker wands after trial 3 and 6”

Results

No points raised

Discussion

R2 - comment 13: Line 132 - Spelling 'with'

Respons comment 13:

Adjusted in the manuscript: line 143

(highlighted in green, as this was raised by the previous reviewer as well).

R2 - comment 14:

Line 137 - Can you please clarify which angular relationship and in which plane recorded the values of 1.29 degrees.

Respons comment 14:

We agree with this statement and chose to refer to table 3 in which the angular relationship is clarified. In our opinion, this would be more apparent than adjusting the sentence, which would not be fluent anymore.

We hope the reviewer agrees with this statement