**Response to Editor and Reviewers:**

*Your manuscript, JoVE58611R1 “Probing and training seated balance with unstable support, motion tracking, and sensory feedback,” has been editorially and peer reviewed, and the following comments need to be addressed. Note that editorial comments address both requirements for video production and formatting of the article for publication. Please track the changes within the manuscript to identify all of the edits. After revising and uploading your submission, please also upload a separate rebuttal document that addresses each of the editorial and peer review comments individually.*

Thank you very much for handling our manuscript and for inviting us to submit a revised version based on the reviewers’ feedback. The comments of the editorial board and reviewers were highly constructive and have helped us to significantly improve the quality of our manuscript. In what follows, we respond to each comment individually and point out respective changes to the manuscript, where applicable. Note that all changes to the manuscript have been highlighted in red to allow their easy identification. We are confident that the revised version of the manuscript addresses all comments and that the content of the manuscript is now acceptable for publication in the *Journal of Visualized Experiments*.

**Editorial Comments:**

Thank you very much for the constructive comments, which helped us to significantly improve our manuscript. We have now revised our manuscript according to the editorial comments.

**Comment 1:** *Please expand your Introduction to include the following: The advantages over alternative techniques with applicable references to previous studies; Description of the context of the technique in the wider body of literature; Information that can help readers to determine if the method is appropriate for their application.*

We thank the reviewer for their comment. We now refer to previous studies for context, as well as to highlight that the advantage of our method is the ability to combine existing rehabilitation techniques into a single accessible and portable device (lines 59-61). We have also explicitly described the appropriate applications of our methods (lines 62-64).

**Comment 2:** *Please note that your protocol will be used to generate the script for the video, and must contain everything that you would like shown in the video.****Please add more specific details (e.g. button clicks for software actions, numerical values for settings, etc) your protocol steps.****There should be enough detail in each step to supplement the actions seen in the video so that viewers can easily replicate the protocol.*

* + - * + *1.1, 1.2: Construct how exactly? Mention equipment used.*
        + *1.2, 1.3: Both made of polyethylene?*
        + *1.5,1.7: What material I used for the sleeve, cylinders?*
        + *1.7: Unclear how the curved surface is prepared.*
        + *1.9: Mention specifications of the steel bar.*
        + *2.1: Mention specifications for the inertial measurement unit, vibrating tactors etc.*
        + *3.1: Mention any exclusion criteria.*
        + *3.2.1-3.2.5: For all software-control steps, mention all button clicks and menu selections.*

Thank you for the comment. The equipment used in the construction process included milling machines, turning machines, welding machines, and a bandsaw; these are now mentioned explicitly in the protocol (lines 75-117). We now also list the material type for each part.

In response to this comment and the first reviewer’s second major concern, the 3D solid model and drawing files for all parts have been made available, as we agree that this will put the audience of the article in a better position to replicate the structural components. The explicit part dimensions are listed in the respective drawing files. Furthermore, to improve readability, the part dimensions have been removed from the written protocol as they are now redundant. To facilitate the replication of the protocol, we have also:

* included the specifications for the electronic hardware (lines 121-123);
* clarified that the exclusion criteria for participation in the experimental study were neurological disorders, musculoskeletal disorders, and back pain (lines 164-165); and
* included the description of all button clicks for all software steps (lines 184-206).

**Comment 3:** *Please highlight ~2.5 pages or less of text (which includes headings and spaces) in yellow, to identify which steps should be visualized to tell the most cohesive story of your protocol steps.*

*1) Presumably several of your steps would need to be filmed in a machine shop, please double check the feasibility of filming there.*

*2) Please ensure that the manuscript title best reflects the filmable content (i.e. the portions you highlight).*

*3) The highlighting must include all relevant details that are required to perform the step. For example, if step 2.5 is highlighted for filming and the details of how to perform the step are given in steps 2.5.1 and 2.5.2, then the sub-steps where the details are provided must be included in the highlighting.*

*4) The highlighted steps should form a cohesive narrative, that is, there must be a logical flow from one highlighted step to the next.*

*5) Please highlight complete sentences (not parts of sentences). Include sub-headings and spaces when calculating the final highlighted length.*

*6) Notes cannot be filmed and should be excluded from highlighting.*

*7) Please bear in mind that software steps without a graphical user interface/calculations/ command line scripting (e.g. steps that describe the Arduino programming, 3.3) cannot be filmed.*

Thank you for the detailed instructions. We have made several changes in response to this comment. The highlighted text now includes ~2.5 pages of text forming a cohesive narrative, including all relevant details that are required to complete each step. The highlighted text includes complete sentences only and no notes. In addition, software steps were associated with respective graphical user interface instructions. We have also revised the title to better reflect the highlighted content (lines 3-4).

We are indeed allowed to film in the machine shop, but may not be able to film the actual process of manufacturing the wobble board. Rather, we propose to sequentially move, in the video, from one machine to the next while narrating what has been done at each machine (Protocol Items 1.1 through 1.8) and showing respective components on the finished wobble board.

**Comment 4:** *JoVE articles are focused on the methods and the protocol, thus the discussion should be similarly focused. Please ensure that the discussion covers the following in detail and in paragraph form: 1) modifications and troubleshooting, 2) limitations of the technique, 3) significance with respect to existing methods, 4) future applications and 5) critical steps within the protocol.*

Thank you for this constructive comment. We have revised the Discussion section to include explicit troubleshooting instructions (lines 339-343). The limitations of the methods pertain to the complexity of relating measured kinematics to balance disorders or improvements (lines 348-349) and the yet unresolved nature of haptic feedback optimization (lines 355-356). The significance with respect to other methods is our device’s accessibility and portability, which we now mention explicitly (lines 332-334). We now also list future applications (lines 359-361). Critical steps within the protocol are the selection of task difficulty (lines 336-337) and the configuration of the vibrotactile feedback (lines 355-356).

**Comment 5:** *Please expand the legends to adequately describe the figures/tables. Each figure or table must have an accompanying legend including a short title, followed by a short description of each panel and/or a general description.*

Thank you for the comment. We have expanded the figure and table legends and included a short title for each. Please see the highlighted changes (red font) in the revised document.

**Comment 6:** *Please use superscript citation format (edit Lines 262-265, 271-274, 274-286)*

Thank you. We have revised the manuscript accordingly.

**Comment 7:** *If your figures and tables are original and not published previously or you have already obtained figure permissions, please ignore this comment. If you are re-using figures from a previous publication, you must obtain explicit permission to re-use the figure from the previous publisher (this can be in the form of a letter from an editor or a link to the editorial policies that allows you to re-publish the figure). Please upload the text of the re-print permission (may be copied and pasted from an email/website) as a Word document to the Editorial Manager site in the “Supplemental files (as requested by JoVE)” section. Please also cite the figure appropriately in the figure legend, i.e. “This figure has been modified from [citation].”*

Thank you for the comment. We have now obtained permission to re-use two particular figures from a previous publication (Figures 1 and 2 in: Williams, A. et al. Design and Evaluation of an Instrumented Wobble Board for Assessing and Training Dynamic Seated Balance. J. Biomech. Eng. 140, 1–10 (2018)). The permission statements have been included as a PDF document in our submission under the section “Supplemental files (as requested by JoVE)”. The file name is: “JoVE\_58611\_ReprintPermission\_ASME\_R2”.

We have also revised the figure captions of Figures 4 and 6 in the submitted manuscript to include the requested information (“This figure has been modified from Williams et al.18”). To adhere to the requirements of ASME, we have also added the following statement: “Republished with permission of ASME, from “Design and Evaluation of an Instrumented Wobble Board for Assessing and Training Dynamic Seated Balance” in the Journal of Biomechanical Engineering, AD Williams, QA Boser, AS Kumawat, K Agarwal, H Rouhani, AH Vette, vol. 140, April 2018; permission conveyed through Copyright Clearance Center, Inc.”

**Reviewer 1:**

Thank you very much for the constructive comments, which helped us to improve our manuscript significantly. We have now revised our manuscript according to the reviewer’s comments.

**Major Concern 1:** *Statistical procedures and experimental details regarding the data presented in the manuscript are unclear. Specifically, it should be make clear if the F-test is referring to the ANOVA analysis? Was repeated measures design used? Is it 2-way (balance conditions and vibration). Moreover, how is the visual information (eyes open/closed) taken into account? And why aren't both conditions presented in data figures (Fig 8-11)?*

We thank the reviewer for their comment – we agree that some further clarification on the statistical procedure would be valuable for the reader. A linear mixed effects model was used to account for the correlation of repeated measurements from each participant. In our model, there are two fixed-effects factors: (1) the balance condition, i.e., the combined effect of changing the eye condition and stability level, as these changes were always carried out concurrently (***although we are aware that they do not need to be, if an experimenter wishes to identify their effects separately; we did so to simplify the analysis for demonstration purposes***); and (2) the vibration condition. In addition to these two fixed-effects factors, the model includes a random-effects factor that varies by participant. The significance of the fixed effects was analyzed by an F-test of the ratio of the variance between group means to the variance of the residuals (ANOVA). We have revised Item 3.4 in the protocol section of our manuscript (lines 225-231), explicitly describing the terms of the linear mixed model and F-test. We have also clarified the use of ‘balance condition’ that combines base difficulty and eye condition (lines 171-179 and lines 242-244).

**Major Concern 2:** *line 71-121: Section 1: Construction and Assembly of Structural Components section details are thorough, however for someone without machine tools background (e.g., rehabilitation specialists, etc) it may be difficult to replicate the details and instructions outlined. I wonder if there is a more "accessible" way to guide them. Perhaps making the CAD files available may be helpful?*

We thank the reviewer for their comment. We agree that the current description of our procedure may be difficult to replicate for someone without a background in machine tools. In response to this comment, the 3D solid model and drawing files have been made available for all parts – to better guide the replication of the structural components. The explicit part dimensions are listed in the respective drawing files. Furthermore, to improve readability, the part dimensions have been removed from the written protocol as they are now redundant.

**Major Concern 3:** *line 128: Similarly, it may be of use to provide some sample code for how to "program" the microcontroller? Also, despite the list in the "Table of Materials", it may be useful to refer to the devices (microprocessor, IMU, vibrating devices) in the text here.*

In response to this comment, we have now included sample code for the microcontroller in the revised submission package (‘wobble\_board\_controller.ino.ino’) – and refer to it in Protocol Item 2.1.1. (line 137-138). In the revised manuscript text, we now also provide details on the used devices (microprocessor, IMU, vibrating devices) as suggested (lines 121-123).

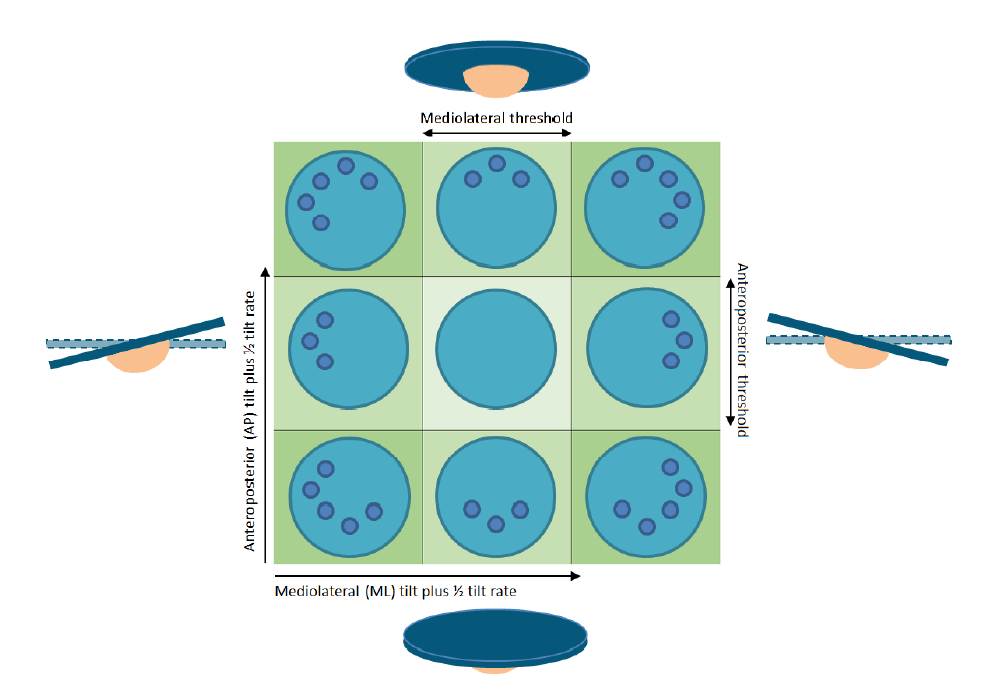
**Major Concern 4:** *line 195-197: Please clarify details regarding selecting threshold based on "previous performance". Would this would make the system adaptive? And would affect performance during training or intervention? Is this desirable? This is a major concern and should be clarified.*

Thank you for the comment. We agree that further clarification is needed regarding threshold selection. The computed threshold values displayed in the “Q3” column of the Arduino Interface (Figure 6) are equal to the third quartile for each tilt direction (AP, ML) during the previous trial. In Protocol Item 3.2.5., we have clarified the instruction to select a threshold based on the quartile results of the fourth familiarization trial (lines 201-214). Note that four trials have been found to be sufficient to achieve a stable performance of the balance task (Larivière et al. 2013).

Our feedback scheme is based on the notion that balance function is improved when feedback intervention is optimized for each individual (Goodworth, Wall, and Peterka 2009; Loughlin, Mahboobin, and Furman 2011), while providing too much feedback may detriment learning (Marchal-Crespo and Reinkensmeyer 2009). Once the two threshold values have been selected for a given individual, they can be kept constant for that individual to be able to assess improvements over time or with an intervention. In the Discussion section, we address the yet unresolved optimization of haptic feedback design as a limitation of this protocol (lines 355-356).

**Major Concern 5:** *line 191: "… closest to left, right, front or back….." how does this correspond to the 8 different vibration instruments on the board? Moreover, how did you activate the ones arranged at 45 degrees? Did you calculate the tilt angle somehow?*

Thank you for the comment. The eight enclosures are arranged to accommodate two-, four, or eight-directional configurations. In the current protocol, the overall *tilt direction* (based on AP and ML tilt) was not calculated, and the vibration instruments at 45 degree angles are used only to augment the vibration at the left or right (based on ML tilt) and the front or back (based on AP tilt). This activation scheme was based on the notion that added directional resolution is only as effective as a four-directional tactor configuration for vibrotactile feedback during standing balance (Sienko et al. 2010). The figure below should help to clarify the feedback configuration. We have made revisions to Protocol Item 2.1.1. (lines 137-142) to clarify this procedure for the reader. We specifically state: “The computer activates three tactors closest to the left, right, front, or back of the surface when the control signal exceeds a threshold in that direction, or five tactors if an AP and ML threshold are surpassed simultaneously; none of the tactors are active when the control signal is below the threshold in both directions (i.e., in the no-feedback zone).”



**Major Concern 6:** *line 226: How were 288 trials analyzed for the 12 participants? Were repeated trials averaged for each condition/participant or not? This is important to ensure p-values are not inflated (i.e., sample size remains n=12). Please clarify.*

Using a linear mixed model, repeated trials are averaged for each condition, and the variance between the group means is compared to the variance of the residuals. The variance between participants is estimated separately, improving the statistical power. As such, the sample size remains n = 12. To clarify this aspect for the reader, we have revised Protocol Item 3.4. (lines 225-231), explicitly describing the terms of the statistical model and significance test.

**Major Concern 7:** *line 242: Could the effect of vibration, which was shown to increase centroidal frequency be due to the mechanical effect of the vibration rather than the effect on the postural control? Please comment and clarify this important point.*

We thank the reviewer for their comment – this is an interesting question. While the tactors on our device vibrate with a relatively high frequency of 200 Hz, we have found in preliminary static and dynamic tests (using different constant weights instead of seated users) that their activation and activity do not affect the motion of the wobble board. These results agree with the design notion that the tactors were not directly attached to the wobble board, but resting on a locating pin – allowing the tactors to move without influencing wobble board motion.

**Minor Concern 1:** *line 26-27: It is unclear if the sitting platform "dynamically destabilizes sitting posture" actively (e.g., via actuators) or passively (i.e., since it is a challenging postural tasks / unstable surface). This should be made clear throughout the manuscript (other examples include line 35, line 59).*

Thank you for the comment. We agree that it should be made clear that the sitting platform *passively* destabilizes sitting posture. We have revised this distinction in the manuscript at three different locations (line 26; line 35; line 58).

**Minor Concern 2:** *Could Fig 8-11 be combined into one figure? Also, could parts of Fig 1-6 also be combined instead of being separated figures?*

Figures 8 to 11 (now: Figures 7 to 10) could potentially be combined, but since each of the bar plots occupies a unique range and scale, we believe that separate figures will help the viewer to understand, at a glance, the differences between conditions. Figures 4 and 5 have been combined into one figure.

**Minor Concern 3:** *What are the units on the y-axis of Fig 8-11?*

The units are currently listed below the x-axis with the measure description, as they are not consistent for all bars plotted in a given figure (e.g., deg versus deg/s or Hz versus no units).

**Minor Concern 4:** *Table 1 is unclear. Please elaborate.*

The title of Table 1 was unclear and has been revised to read: “Geometrical properties of the interchangeable bases. The total height of each base module is 63 mm; thus, a base with a smaller radius of curvature, when attached to the device, is less stable than a base with a larger radius of curvature” (lines 320-322).

**Minor Concern 5:** *line 55: What "protocols" are you referring to?*

Thank you for pointing this out. The protocols referred to were not identified. Line 54 now reads “current sensory feedback methods.”

**Minor Concern 6:** *line 63: it would be useful to add a reference for the "posturographic measures"*

We agree with the reviewer. We now refer to Prieto et al. 1996 (line 62).

**Minor Concern 7:** *line 153: Why is the size 10x8cm? Is this based on anatomical measures? If so, please use a citation here.*

The tactors were placed so that they will lie under the buttocks of an average-sized person. We now make reference to Churchill and McConville 1976 (line 146).

**Minor Concern 8:** *line 173: Why 30 second trails? Is this sufficient? Also, please add a reference.*

30-second trials can adequately assess upper body stability, according to Lee and Granata 2008. We now include respective reference (line 168).

**Minor Concern 9:** *line 177: Again, please add a reference for the eyes open/closed design.*

The point is well taken. We now refer to Silfies, Cholewicki, and Radebold 2003 (line 173).

**Minor Concern 10:** *line 188: Is "log and monitor" done on the microcontroller or in Labview? Is this done in real-time (one would assume)?*

Yes, the tilt angles are sampled and communicated serially to Labview, where they are logged to a text file, in real-time. Protocol Item 3.3 (line 216) has been revised to read: “The AP and ML signals are automatically stored, in real-time, in a text file for analysis.”

**Minor Concern 11:** *line 196: Please clarify if for example it is possible for front and back simultaneously?*

It is possible for front and left, for example, to be activated simultaneously. However, it is not possible to activate front and back simultaneously. We have revised Protocol Item 2.1.1. to clarify this (lines 137-142). See also the figure above, in response to this reviewer’s *Major Concern 5*.

**Minor Concern 12:** *line 214-216: It would be helpful to provide a brief description of the measures listed here.*

Thank you, we have added a brief description of each measure in Protocol Item 3.3 (lines 216-223).

**Reviewer 2:**

**Summary:** *the manuscript is well written and the issue is of importance in spine stability*

We are pleased to hear that the reviewer believes our manuscript is well written and that the underlying study is important in the domain of spine stability. We have provided detailed responses to the reviewer’s specific comments below.

**Minor Concern 1:** *it would be good if the authors refer to wobble chairs in the text*

We thank the reviewer for their comment – we agree that wobble chairs should be mentioned in the text, as they bear resemblance to our device, and their study has guided parts of ours. In our revised manuscript, we explicitly refer to wobble chairs in the Introduction section (lines 59-61) and Discussion section (line 332-334).

**Reviewer 3:**

**Summary:** *The device provides an interesting way of challenging and measuring sitting balance.*

We are pleased to hear that the reviewer finds our methods interesting. We have provided detailed responses to the reviewer’s specific comments below.

**Minor Concern 1:** *It appears that Table 2 and the Figures may be redundant.*

We thank the reviewer for their comment – we agree that Table 2 gives the same essential result as Figures 7 to 10 (previously: Figures 8 to 11), so may be redundant. Nonetheless, we feel that readers may benefit by having access to the numerical results in each experimental condition (Table 2) and the differential results depicted by Figures 7 through 10 (previously: Figures 8 to 11).

**Minor Concern 2:** *Table 2 can't stand alone as abbreviations are not designated.*

Thank you for the comment. Abbreviations in Table 2 have been revised to their full designations.

**Minor Concern 3:** *References are presented inconsistently.*

We thank the reviewer for their comment. There has been an issue with the citation plug-in, which has now been corrected.

**References for Response Letter:**

Churchill, Edmund, and John T. McConville. 1976. “Sampling and Data Gathering Strategies for Future USAF Anthropometry.” http://www.dtic.mil/docs/citations/ADA025240.

Goodworth, Adam D, Conrad Wall, and Robert J. Peterka. 2009. “Influence of Feedback Parameters on Performance of a Vibrotactile Balance Prosthesis.” *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 17(4): 397–408.

Larivière, Christian et al. 2013. “Criterion Validity and Between-Day Reliability of an Inertial-Sensor-Based Trunk Postural Stability Test during Unstable Sitting.” *Journal of Electromyography and Kinesiology* 23(4): 899–907.

Lee, HyunWook, and Kevin P Granata. 2008. “Process Stationarity and Reliability of Trunk Postural Stability.” *Clinical Biomechanics* 23(6): 735–42.

Loughlin, Patrick, Arash Mahboobin, and Joseph Furman. 2011. “Designing Vibrotactile Balance Feedback for Desired Body Sway Reductions.” In *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, , 1310–13.

Marchal-Crespo, Laura, and David J Reinkensmeyer. 2009. “Review of Control Strategies for Robotic Movement Training after Neurologic Injury.” *Journal of neuroengineering and rehabilitation* 6(1): 20–35. http://www.scopus.com/inward/record.url?eid=2-s2.0-68249158648&partnerID=tZOtx3y1.

Prieto, Thomas E. et al. 1996. “Measures of Postural Steadiness: Differences between Healthy Young and Elderly Adults.” *IEEE Transactions on Biomedical Engineering* 43(9): 956–66.

Sienko, Kathleen H., Vivek V. Vichare, M. David Balkwill, and Conrad Wall. 2010. “Assessment of Vibrotactile Feedback on Postural Stability during Pseudorandom Multidirectional Platform Motion.” *IEEE Transactions on Biomedical Engineering* 57(4): 944–52.

Silfies, Sheri P., Jacek Cholewicki, and Andrea Radebold. 2003. “The Effects of Visual Input on Postural Control of the Lumbar Spine in Unstable Sitting.” *Human Movement Science* 22(3): 237–52. http://linkinghub.elsevier.com/retrieve/pii/S0167945703000460.