Response to Editorial Comments and Reviewers:

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.

*The manuscript has been thoroughly proofread for errors.*

1. Please upload each Figure individually to your Editorial Manager account as a .png or a .tiff file. Please combine all panels of one figure into a single image file.
2. Many of the Figure panels can be supplementary Figures used only for the scripting. Please remember that there will be a video component as well. Please reduce the number of Figure panels.
3. Figure 2 may be effective if only showing the picture of person in the various stances. Figure 6 is a bit cluttered and may not be clear when all the panels are included in one image file. Is there another way to present Figure 8?

*Several edits were made to the figures as follows: The number of panels was reduced for Figures 2, 3, 5, and 6 and these were placed into a single image file. We attempted to combine several outcomes from Figure 8 onto one plot, however, this was not a statistically sound approach to visualize our data as 5 of the remaining 6 plots utilize different scales. However, we eliminated three outcomes that were not as relevant and combined the remaining 6 into one image file. In all, we have reduced the original number of figures by one-third.*

1. Please place the superscripted reference before the punctuation.

*This has been corrected.*

6. Please use SI abbreviations for time: h, min, s, ms, etc.

*Abbreviations have been corrected.*

7. JoVE cannot publish manuscripts containing commercial language. This includes trademark symbols (™), registered symbols (®), and company names before an instrument or reagent. Please remove all commercial language from your manuscript and use generic terms instead. All commercial products should be sufficiently referenced in the Table of Materials and Reagents.  
For example: iPad (use tablet instead), etc.

*All references to commercial products have been removed from the manuscript and detailed in the Table of Materials and Reagents.*

8. Please ensure that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., “Do this,” “Ensure that,” etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as “could be,” “should be,” and “would be” throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a “Note.” However, notes should be concise and used sparingly. Please include all safety procedures and use of hoods, etc.

9. The Protocol should contain only action items that direct the reader to do something. Please move the discussion about the protocol to the Discussion.

10. Please include an ethics statement before the numbered protocol steps, indicating that the protocol follows the guidelines of your institution’s human research ethics committee.

11. I have renumbered the protocol steps for clarity.  
12. Step 1 and 2 of the protocol can be move to the Introduction.  
13. Please remove the large paragraph of text in Step 8.

*The protocol has been edited to ensure that all text are written in the imperative tense. Descriptions of the protocol have been moved to the Discussion or to the Introduction as appropriate. An ethics statement was added as suggested.*

14. Please highlight 2.75 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol. Remember that non-highlighted Protocol steps will remain in the manuscript, and therefore will still be available to the reader.

15. Please ensure that the highlighted steps form a cohesive narrative with a logical flow from one highlighted step to the next. Please highlight complete sentences (not parts of sentences). Please ensure that the highlighted part of the step includes at least one action that is written in imperative tense.

*Relevant steps of the protocol have been highlighted to define the visual portion of the manuscript.*

16. Please spell out all journal titles.  
  
*Journal titles are now spelled out.*

**Reviewers' comments:**  
  
  
Reviewer #1:  
  
Manuscript Summary:  
the C3 application demonstrates the ability to differentiate standard recovery and prolonged recovery in student athletes. Though, further testing for sensitivity is required, the results appear to be promising.  
  
  
  
Reviewer #2:  
  
Manuscript Summary:  
Thank you for the opportunity to review your work. A multidisciplinary approach is positive. However the target audience (users and subjects) needs to be more clearly defined. How does this technology advance what is currently available.  
More references are needed to support rational for measures selected.

*We appreciate these comments and have updated the manuscript to clearly communicate how this multidisciplinary approach is critical to effective management of concussion.*   
  
Major Concerns:  
1. How is this protocol with technology different/similar to what is currently available ie Im PACT, NIH tool kit ? others?

*While our aim is not to compete with other concussion assessment tools, we appreciate the opportunity to describe the differences in our approach to concussion assessment using the C3 app. From an assessment perspective, traditional measures including ImpACT and CNS Vital Signs only assess neuropsychological function. Yet, it is widely known that the deficits following concussion are multi-modal and may include declines in motor function, motor control, postural stability and vision. Thus, the C3 app was developed to include biomechanical measures of these additional domains of neurological function not traditionally captured using other tools. For example, the iPad is affixed onto the sacrum to provide a biomechanical measure of postural sway while individuals complete the 6 stances of the BESS. These data are converted to percentile scores based on a normative database of over 6000 student-athletes. The app also includes the assessment of static and dynamic visual acuity, which is novel compared to other assessment tools. Of note, we have further developed this iPad-based suite of visual outcomes which is beyond the scope of this manuscript, but has promising clinical implications. Also, the neuropsychological measures included in the app are not simply paper-pencil tests converted to a tablet platform. Rather, each test exploits the capacitive touch screen to provide detailed data regarding aspects of performance. For example, during the Trail Making Test, while the standard outcome is time to complete, we are able to distinguish “dwell time”, or the time the individual is thinking about or searching for the next target, from “movement time”, or the time required to move between targets. These detailed data provide additional information regarding the individual’s deficits as related to cognitive versus motor function. Lastly, the results of the app align with the carepath and populate fields in the electronic medical record, allowing all members of the concussion management team to review this common set of data elements. While we feel these distinctions are beyond the scope of this protocol paper and have been outlined in our previous publications, should the reviewer feel that it enhances the manuscript, we are happy to add it.*

2. What is the rationale and references behind the tests selected for this technology? Are they NINDS common data elements? CDC approved elements?

*NINDS recommends numerous proprietary outcome measures and several non-proprietary. In collaboration with our team of neuropsychologists, we chose measures that are either recommended by NIH (ie: Trail Making Test, SAC) or are proxies that measure comparable domains of function (e.g.: assessment of static and dynamic visual acuity instead of provocation testing using the VOMS). The Processing Speed Test was developed and validated based off of the paper-pencil symbol digit modalities test. The instrumented BESS is used due to its historic role in concussion assessment and it is recommended by NINDS.*

3. How does this process support more care co-ordination between health care professionals?

*Prior to the development and implementation of the carepath and C3 application, the various disciplines involved in concussion care at our institution used different outcomes and different systems for documentation (ie: athletic trainers kept paper records stored in files in the training room at each school). The app combined with the carepath served three main purposes in improving care coordination: 1) unify outcomes across the multidisciplinary team, 2) standardize decision-making based on objective outcomes, and 3) enable documentation with respect to the collection of outcomes to be collected on the iPad platform which was then included in the electronic health record. The second and fourth paragraph of the discussion now outline these processes.*

4. Clarify the target audience - both in terms of who will use the tool and who will be the subject of the tool/ (seems like young athletes)

*We believe that our somewhat fractionated approach to concussion management, prior to the C3 app and carepath, is reflective of many approaches in hospital systems across North America and Europe. Various aspects of the tool are administered by all members of the interdisciplinary team or direct treatment to a member of the team. This includes athletic trainers, nurses, physicians (sports med, neurologists, physical medicine and rehabilitation, otoneurologists, sleep medicine, pediatricians, neuroradiologists, ED physicians), physical therapists, and speech and language pathologists. Unlike the care pathway developed by the Ontario Neurotrauma Foundation (referenced below), our carepath is designed for use by medical personnel.*

*The carepath was created for individuals between the ages of 12 and 50. Modules of the C3 app have been administered in individuals from 5 years to 80+, though normative values are available for individuals ages 5-24.*

5. Amend title to fit target group

*The title has been amended to: Development and Implementation of a Multi-Disciplinary Technology Enhanced Care Pathway for Youth and Adults with Concussion*

6.What is meant by a value-based model in this context?

*The first paragraph of the introduction is meant to define value-based care with respect to the context of the carepath (e.g. third- party focus on tying payments to outcomes rather than a traditional transactional fee-for-service reimbursement model). We describe perspectives regarding how disjointed care that lacks continuity contributes to overutilization and poor coordination of resources, but that “In a coordinated care model, patients with a given condition are managed by an experienced, interdisciplinary team according to best practice guidelines, and are referred to the right provider at the right time2.”*

7. What is someone has neck pain/injury - how to visual testing?

*The reviewer poses an important question. Dynamic visual testing is often deferred until the athlete is asymptomatic and does not have cervicogenic dysfunction that may be worsened with testing. Dynamic visual testing can also be used as a provocative assessment in athletes to determine whether residual vestibular or cervicogenic dysfunction is present. Step 7.1 of the protocol has been amended to reflect this important detail.*

8. What about those with previous concussions?

*Those with previous concussions are more likely to experience protracted recovery. This “modifier” along with others (h/o migraines, ADD, anxiety, etc) is included in the carepath (see Figure 1) and in step 7.4 of the protocol when determining the timing of referral to specialty services.*

9. How many times can the C3 module be repeated? reliability ? validity ?

*Several of the C3 app modules have undergone reliability and validity testing both internally and externally (see references 13, 15, 17, 18, 20, and 21). A shift in post-concussion testing has occurred in the past 3-5 years, in that testing is used primarily to determine whether an individual has fully recovered and is cleared for some level of participation (school, work, sport, etc). A part of the C3 app that does not succumb to learning effect is the graded symptom checklist. This important tool, when combined with portions of the app (balance testing, for example), are often sufficient to inform the clinician regarding next steps in clinical management. Frequent administration of the entire app (ie: all modules) is discouraged to preserve the psychometric properties of the tool and to prevent unnecessary symptom provocation. While we appreciate the “standardization” of care with the carepath and the app do not take the place of sound clinical judgment in the application of these tools.*

other references for the authors to consider :  
  
a) [http://concussionsontario.org/wp-content/uploads/2018/04/ONF-PatientPathway-Tearaway-WEB-1.pdf](https://protect-us.mimecast.com/s/0lD1CW6vMAtjAq2KT1FjlC?domain=concussionsontario.org)  
b) Vander Vegt CB, Register-Mihalik JK et al. Baseline Concussion Clinical Measures Are Related to Sensory Organization and Balance. Med Sci Sports Exerc. 2018 Sep 19. doi: 10.1249/MSS.0000000000001789

*We appreciate the recommendations and both references have been added.*   
Minor Concerns:  
1. Are OTs and nurses not part of the multidisciplinary team?

*Nurses play a prominent role in the multidisciplinary team. In our practice, very few concussion patients are referred to OT, except occasionally for vision rehabilitation, though this is primarily accomplished through an optometrist who has developed a niche in this domain. Nonetheless, both disciplines are certainly respected in the field and should be considered a part of the team. The manuscript has been edited to reflect this.*

2. Explain more about being HIPPA compliant.

*All assessment data are encrypted at rest and in transmission to the Amazon Web Services cloud. Further security and encryption measures are provided by ClearData before data are transmitted to an existing HIPPA compliant research database behind the Cleveland Clinic firewall. All points of access to the research database take place over Transport Layer Security/Secure Sockets Layer encrypted connections. This data collection and transmission approach has been approved by multiple groups and committees within the Cleveland Clinic: IRB, Office of Compliance, Legal, Information Technology Division (ITD) security and governance, Office of Patient Engagement, Enterprise Information Management and Analytics and Mobile Governance Committee. All iPads are enrolled in the Cleveland Clinic’s Mobile Device Management (MDM) system. The Cleveland Clinic MDM has the ability to track the location of each device. Each iPad requires a double lock system – one password to get into the iPad and another to access the C3 assessment application. Should a device be lost or stolen, the MDM administratively locks and remotely wipes the device.*

3. What is the definition of concussion used by the physician ( line 369)

*While in the carepath document we acknowledge that there is no universally agreed upon definition of concussion, we chose to use the definition based off of the 4th International Conference on Concussion in Sport: A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. This part of the manuscript is now referenced.*

4. Figure 1 does not match with the content of the manuscript- it needs a title .

*Figure 1 depicts the algorithm developed with the carepath to guide clinical care in each post-injury phase. A title has been added.*

5. References are not complete on the draft I have received  
  
*We are unsure if a page was omitted from the draft received by the reviewer. There are currently 23 references.*  
  
Reviewer #3:  
  
Manuscript Summary:  
The authors nicely describe the process and care pathway of use of the C3 within their system.  
  
Major Concerns:  
None, very well done.  
  
Minor Concerns:  
Figure 8, please include units on y-axis, add error bars.

*Thank you for the recommendations. Figure 8 has been edited as recommended.*