Dear Dr. Jialan Zhang,

c\o Dr. Alisha DSouza,

Thank you very much for the constructive reviews of our manuscript “Impacts of free-falling spheres onto a deep liquid pool with altered fluid and impactor surface conditions.” In keeping with the recommendations of the reviewers, we make corrections to the manuscript and hereby submit our revisions for further scrutiny. We believe the new manuscript is improved in readability and offers more clarity as compared to the previous version.

As detailed in the attached point-by-point list of responses, we have attempted to implement most of the suggestions.

We hope that this explanation and our attempts to translate same into the revised manuscript adequately address your concerns. We look forward to any further additions and corrections to our manuscript.

Yours sincerely,

Andrew Dickerson, Daren Watson, Jeremy Stephen

**Editorial Comments to Author**

Changes to be made by the author(s) regarding the manuscript:

Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues.

We proofread manuscript for spelling and grammatical errors.

Abstract (150-300 words): Please expand it to provide an overview of the advantages, limitations and applications of the protocol.

We adjusted the abstract which now reads:

“Vertical impacts of spheres on clean water have been the subject of numerous water entry investigations characterizing cavity formation, splash crown ascension and Worthington jet stability. Here, we establish experimental protocols for examining splash dynamics when smooth free-falling spheres of varying wettability, mass, and diameter impact the free surface of a deep liquid pool modified by thin penetrable fabrics and liquid surfactants. Water entry investigations provide accessible, easily assembled and executed experiments for studying complex fluid mechanics. We present herein a tunable protocol for characterizing splash height, flow separation metrics, and impactor kinematics, and representative results which might be acquired if reproducing our approach. The methods are applicable when characteristic splash dimensions remain below approximately 0.5 m. However, this protocol may be adapted for greater impactor release heights and impact velocities, which augurs well for translating results to naval and industry applications.”

Please renumber the references in the text; currently the reference number starts from 2.

We rechecked and renumbered references in the text.

7.1-7.4: Software steps must be more explicitly explained ('click', 'select', etc.). Please add more specific details (e.g. button clicks for software actions, numerical values for settings, etc.).

We adjust the steps with further details and incorporated button clicks where applicable.

Representative Results: Please remove the subheadings.

All subheadings removed.

Figure 3: Please define error bars in the figure legend.

We now define error bars in all figure legends and add a sentence to the caption stating what they represent.

Table of Materials: Please sort the items in alphabetical order according to the name of material/equipment.

Items checked and sorted in alphabetical order according to the name of the material/equipment.

**Reviewer #1 Comments to Editor and Author**

This manuscript presents a standardized protocol for observing splash dynamics of a rigid sphere impacting onto a deep pool of fluid. It provides detailed guidelines for the releasing mechanism of the rigid sphere, the pool of fluid, fabrication of the rigid sphere, surface modification of the sphere, and analysis of the splash and its relevant parameters. Splash dynamics is a widely studied field and this appears to be the first paper to explicitly describe a standardized protocol for studying splashes of rigid spheres. This paper would be of particular interest for engineers.  
  
**Major Concerns**

I have no major concerns.  
  
**Minor Concerns**

The parameters presented in Fig. 3 should be presented in the main text for clarity. Currently, they are only in the figure captions.

We adjusted the corresponding text in “Digitizing Impact Kinematics with Tracker Software”. The sentence now reads:

“A measuring stick is used to extract splash crown height κ, cavity width β, cavity depth λ, and Worthington jet height h, as seen in Figures 2b – c.”

What do the error bars in Fig. 3 represent? This should be stated in the caption.

We believe the referee was referring to Figure 4. Therefore, we inserted the following sentence into the caption:

“Error bars denote standard deviation for the average of five trials at each point.”

**Reviewer #2 Comments to Editor and Author**

This manuscript describes an experimental apparatus and procedure for dropping spheres into a liquid basin while controlling for and measuring a variety of variables relating to the cavity dynamics, splash crown dynamics and sphere trajectory. The authors detail relevant information from previous studies and provide experimental results for a series of operating conditions.

**Major Concerns**

In general, there are some useful details provided in the paper, however it would benefit from great organization and clarity.

In the Introduction section paper 2 is the first one referenced (line 47). Paper 1 should be the first one discussed and referenced in the text.

We thank the reviewer for this observation. We rechecked and renumbered references in the text.

The authors suggest that there is a lack of procedural consistency in published works which could be problematic. What information are the authors using to arrive at this suggestion? It is unclear that there have been issues or inconsistencies in the published data or other problems that have resulted from this.

We agree with the recommendation and seek to soften our stance. The sentence now reads:

“Here, we establish clear in-depth protocols and best practices for achieving consistent results from water entry investigations.”

Much more detail is desired on the drop mechanism in order for a reader to replicate the method developed. In what direction does it retract, how is it made/mounted, how is it triggered, etc.?

We include an image of the release mechanism in Figure 1a to improve clarity for readers. Steps 1.3. and 1.4. were also adjusted and now reads:

“Construct a hinged platform (‘release mechanism’) that suspends spheres above fluid and rotates downward, to achieve tangential acceleration greater than gravity at the impactor location when released, as seen in Figure 1a. Rapid rotation is achieved by connecting the hinged platform to the center of the supporting component using elastic bands. The result is an unsupported and non-rotating impactor. Note: Platform is easily fabricated with 3D printer.”

“For impact trials, place thumb to base of platform and rotate 90o to a horizontal position for placement of spheres above fluid. Note: Retraction is triggered when thumb is released from base of platform.”

Line 113, the authors state the impact velocity is found from an equation that assumes negligible drag. This clearly has limitations and uncertainty. Why is it not recommended to use the software to determine the velocity at impact? Would that not be a "best practice" as opposed to assuming drag doesn't slow the sphere down?

We thank the reviewer for this observation. We address our oversight by modifying the protocol which now reads:

“Conduct experiments over a range of heights *H* to generate impact velocities where m/s2 is the acceleration due to gravity. Measure height with visual scale within the camera frame. Note: Use **Auto-Tracking** feature in video analysis tool as discussed in Section 7, to measure impact velocities.”

The authors recommend some measurements (mass and diameter) but not others (viscosity, density). As the paper seems aimed at the sphere dropping/impacting variables it is recommended that more attention is given to those details. Measuring fluid properties and diameters should be within the realm of all experimentalists and therefore unnecessary to include here.

We agree that measurements such as mass and diameter are trivial, but allow such discussion to remain in the manuscript to satisfy the requirements of the journal. We include discussion of other splash measurements such as jet height, cavity depth and width, separation angle and location, and sphere depth. Additional metrics not included, such as lamella breakup measurements would be very specific to other studies and are therefore not included here. We welcome greater clarification from the reviewer should our manuscript warrant further adjustment.

Why are pre-test trials with a hydrophilic sphere recommended (line 134)? How should hydrophilicity be determined? What is the critical velocity that is referred to here? More likely it is an impact Weber or Froude number that also depends on contact angle between the liquid and solid surface.

We thank the reviewer for this suggestion. We reviewed the step and decided that it is in fact extraneous to the protocol.

Line 181 - what is meant by "verify impact eccentricity" and why is this considered a critical step in synchronizing cameras for splash visualization?

We use the term to suggest that the use of an additional camera allows determination of impact location of the free-falling sphere. However, given that this suggestion is already made in the introduction, we remove the particular phrase from the protocol to prevent redundancy.

It should be noted somewhere in the paper that a separate ruler is needed for above the water and below the water. The water can act to magnify dimensions which would either need to be quantified or shown to be non-existent.

We thank the reviewer for this suggestion. We added the following step (1.2.) which reads:

“Place additional meter ruler under water, which can act to magnify dimensions. This visual scale is used for calibrating tracking software for underwater measurements.”

Line 222 - are the author suggesting that a protractor be held up against the computer screen or something else? More clarification is needed.

We thank the reviewer for this comment and provide clarity by modifying the sentence which now reads:

“Select protractor from toolbox and measure separation angle θ of fluid with respect to the impactor as seen in Figure 2b.”

Section 8 - Calculating Drag at Fluid Entry - seems extraneous to the objective of the paper. It is recommended that this be removed, or much more information be provided so that the reader can understand how this is relevant to the running of sphere impact trials.

We conclude that this section is in fact extraneous to the scope of the paper and agree with the reviewer’s suggestion to have it removed.

The authors provide results that one might get if reproducing their approach, which is fine. However, the reader would need to know the exact experimental condition for every one of the presented data points if they truly wanted to replicate the authors' data. This information is not provided. So the data shown in Figures 2-4 would not be useful, as presented, for comparison purposes. A table could be provided that includes all of the relevant detail needed (drop height, impact velocity, diameter, static contact angle, mass, etc.). Or, if the authors included the data for some other reason this should be clarified and made clear as to how it fits with the main objective of the work. The results are interesting in their own right, but it seems they have already been published and the conclusions drawn from them would not exactly be relevant to the JoVE work.

We include representative results in keeping with the requirements of the journal, and refer the reviewer to another published example: <https://www.jove.com/video/58045/controllable-nucleation-cavitation-from-plasmonic-gold-nanoparticles>

In any case, the reviewer makes a valid argument. Therefore, we have amended the first paragraph of Representative Results to read:

“Our established protocols allow for the observance of the Worthington jets arising from vertical impacts over a range of Weber numbers as seen in **Figure 2c**. These results are published in Watson *et al.* (2018)1, which can be referenced for exact experimental conditions used to produce the data presented herein. We focus on the narrow elongated film of fluid protruding above the free liquid surface. In **Figure 3** we show a meager amount of fabric amplifies splashing while sufficient layering attenuates splash back. Results are non-dimensionalized using the sphere diameter *D* as seen in **Figure 3b**.”

It was good to include a mention of the filtering used for determining trajectory and velocity. This section would benefit from some more detail on the mechanics of this operation.  
We have bolstered our paragraph on the Savitzky-Golay filter in the Discussion. The related paragraph now reads:

“Care should be taken when considering temporal kinematics for theoretical investigations. Temporal position tracks present less distortion than for velocity tracks but require smoothing prior to numerical differentiation1,3,15. The Savitzky-Golay filter performs a polynomial regression on a range of equally spaced values to determine the smoothed value for each point and can more faithfully maintain a track’s salient features11. For tracking sphere position, a second-degree polynomial inside the Savitzky-Golay filter preserves the track’s salient features while removing experimental noise. Finally, researchers have choice of the moving average span of the filter, which should be as small as possible while still achieving the desired level of smoothing.”  
  
**Minor Concerns**

Line 98 states that light is parallel to the camera. In Figure 1 it appears to be angled relative to both cameras. Please clarify.

This sentence now reads:

“Attach a multi-LED light to magic arm such that the light is mounted above the camera, looking down onto the splash zone.”

Lines 164-170 suggest 2 base coats and 2 top coats. Would this not really be 3 base coats and 1 top coat?

The manufacturer for the spray used in our experiment suggests 3 base coats and 3 – 4 top coats for optimal use. We insert the following note into the protocol:

“Note: Number of additional surface coats may vary based on recommendations of product manufacturer.”

The authors might want to consider backlighting for cavity visualization, or at least commenting on this as it seems to be the norm in the published research.

We thank the reviewer for this suggestion and added the following sentence to paragraph 2 of the Discussion which reads:

“The protocol can be further tuned for improved cavity visualization by replacing the black screen in Figure 1a with backlighting, which makes cavity features more pronounced.”

Why is much of the text highlighted in yellow?

We highlight several text in yellow in keeping with the request of the journal’s “**Instruction for Authors**” which reads:

“For a Protocol section that exceeds 3 pages, highlight in yellow up to 2.75 pages (no less than 1 page) of protocol text (including headers and spacing) to be featured in the video. Our scriptwriters will derive the video script directly from the highlighted text.”

Please define Weber number explicitly.

We define the Weber number in “Controlling dimensionless parameters”.

In Figure 2c height is indicated as "h" while in Figure 3 "H" is used. Please be consistent.

“H” has been replaced with “h” in Figure 3 and the text rechecked for consistency.

Please show specific measurements of h, lambda, beta, theta, and kappa on the digital images and define them in the text. Figure 2 alludes to them but seeing the actual lines that indicate their measurement removes confusion.

We adjusted the corresponding text in “Digitizing Impact Kinematics with Tracker Software”. The sentence now reads:

“A measuring stick is used to extract splash crown height κ, cavity width β, cavity depth λ, and Worthington jet height h, as seen in Figures 2b – c.”