Author’s response to reviews

Title: Comparison of the kinematics and kinetics of shoulder exercises performed with constant and elastic resistance

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Author’s response to reviews:

Dear Reviewers

First, we would like to thank to all of you for your excellent comments. They really helped to improve the manuscript. All our answers are in blue color and the changes in the manuscript are highlighted in turquoise.

Best regards, silvio

Reviewer reports:

Kane Middleton (Reviewer 1): The authors have investigated the kinematics and kinetics of the shoulder joint for 10 internal/external rotation exercises. These exercises were performed with both a constant and elastic resistance. Results showed that total RoM was not influenced by resistance type but moments were significantly higher with constant resistance. The authors have undertaken a well designed and written study that has clinical significance in the choice of exercise selection during rehabilitation. Some specific comments can be found below:

Introduction
P4L13: This paragraph introduces the issues with the tracking and modelling of the upper limb. However, this is not an aim of the study. Recent research (Campbell AC, Alderson JA, Lloyd DG, Elliott BC (2009) Effects of different technical coordinate system definitions on the three dimensional representation of the glenohumeral joint centre. Med Biol Eng Comput 47:543-550. https://doi.org/10.1007/s11517-009-0467-7; Campbell AC, Lloyd DG, Alderson JA, Elliott BC (2009) MRI development and validation of two new predictive methods of glenohumeral joint centre location identification and comparison with established techniques. J Biomech 42:1527-1532. https://doi.org/10.1016/j.jbiomech.2009.03.039) has been published that has developed a valid and reliable marker set and modelling approach for definition of the GHJC. Some of this paragraph could be moved to the methods and more detail about your aims and stating some hypotheses could be added to the last paragraph of the

Introduction.

This information has been included in the introduction: Recent research has assessed the effect of different technical coordinate system definition on the three dimensional representation of the glenohumeral joint center (Campell et al., 2009a). It has been shown, that with a skin marker set it is possible to predict the position of the glenohumeral joint center (Campell et al., 2009b).

To allow the analysis of the kinematics and kinetics of the upper extremities, our secondary goal was to use the ISB recommended marker set and to test the transfer of our methods for functional joint center determination of the lower limbs to the joints of the shoulder. Therefore, the goal of the study has been enhanced with:

The second goal of the present study was to design a marker set for functional joint centre determination of the shoulder joints to be able to examine upper extremity kinetics and kinematics in 3D of the selected shoulder strength exercises. The range of motion between the two types of force application, constant and elastic resistance, is expected to show no difference. However, the maximal moments observed, as well as the angles of the maximal moments are assumed to differ between the selected exercises.

Methods

Throughout: Unless otherwise required by the journal, the term participants should be used instead of subjects.

The term subjects has been changed to participants

P5L7: How much weight training experience did the participants have?

The information has been added and reads now:
“Inclusion criteria included participation in sport activities for at least three hours per week and participants were required to be physically fit and have basic experience in strength training.”

P5L21: What is your definition/determination of participants being 'physically fit’?

In the ethics proposal following selection criteria needed to be fulfilled:

Selection criteria:

· Participants do sport activities at least three hours per week.
· Participants are physically fit (no current injuries) and have a RoM that is considered normal in the upper extremities.
· Participants have basic personal experience in strength training.
· Participants are between 18 and 45 years old.

Exclusion criteria:

· Past surgery on the upper extremities.
· Current injury or illness.
· Health problems.
· Under medical treatment.

This information has been included in the new Table 1.

P5L32: "Five of the exercises are thought to train..." Thought by whom? Is this based on first principles or literature? If the latter, please include a reference.

These exercises are part of many shoulder rehabilitation and strength programs and therefore the sentences has been changed to the following: Five of the exercises are designed to train the internal rotator muscles of the shoulder…

P6L39: Please add more detail about how the new marker set differs from those described in previous literature.

A new marker set was developed based on the ISB recommended anatomical landmarks and supplemented further markers on the hand, forearm and upper arm (Angst, 2012; List et al., 2013; Wu et al., 2005)
P6L41. Do you have any validity or reliability data of the marker set?

This limitation has been included in the discussion section: Another limitation of this study is, that the here used marker set has not been directly validated with a gold standard such as MRI.”

P6L57: Please provide some additional detail of how the joints were functionally determined.

Supplementary Table 1 has been inserted, with the description of the basic motion tasks. And the procedure is described in work of List et al. (2013).


P7L39: What was the reasoning for normalizing moments by BW? Technically, you have normalised by mass (kg) rather than weight.

The term “body weight (BW)” was changed to “body mass (BM)”.

Lucy Parrington, PhD (Reviewer 2): SSMR-D-18-00028: Comparison of the kinematics and kinetics of shoulder exercises performed with constant and elastic resistance.

The paper describes a comparison of multiple shoulder rotation exercises under constant and changing (elastic) resistance in 12 (50%) healthy participants. The authors found joint range of motion did not differ across exercises, but that the joint moments were greater with constant resistance. The authors conclude that exercises can be chosen to reflect the needs/ aims of the training. I have few major concerns and overall feel the paper is well written, descriptive and has practical application. The authors have done a good job in providing supporting figures.

Concerns and questions listed below.

Major:

Methods: I see one of the main issues with this assessment relating to gimbal lock and shoulder joint assessment. While the authors acknowledge this as a potential limitation, I would like to know more about what prior pre-submission assessment the study team used when considering their final approach. I do not see this as much of an issue for the internal and external rotation exercises where the shoulder was in a fixed adducted or abducted position, however, I have my concerns for the combined exercise which involves all three rotations. I find this to be of particular importance given the results and discussion of these combined movements, and further the practical application indicated.

Do the authors have some data relating to assessment using different orders of rotation vs. the method they used? Did the authors look to validate the method used in any way regarding the
two rotations of interest? To put it more clearly, how certain are the authors that their data for the combined movements effectively estimates the joint motion?

The authors have intentionally decided only to analyze the abduction/adduction and internal/external joint angles of the GHJ, due to the known challenges of the shoulder joint angle assessment. Further, it was also the goal to keep the description of the angles in an agreement of the anatomical and clinical definitions. All different approaches for joint angle definitions were tested (euler angles, ISB recommended standard (Grood and Suntay, 1983; Wu et al., 2005) and joint coordinate system).

For the GHJC, the flexion/extension axis was defined to be the floating axis (FL), as this was the axis of least importance for the examined movements. With this approach, however, it is possible that gimbal lock occurs, and that the angles cannot be defined over the whole flexion/extension RoMs.

The choice of different orders clearly results in different angular data, and therefore it is crucial to interpret data only based on the underlying methodology and it is also clear that data is not comparable to studies not using the same sequence respectively mathematical convention.

In general, since clinical definitions are only for int/ext rotation based on a single rotation axis and the clinical definition for ab/adduction and flexion/extension are based on motion towards or away from a plane, thus can take place around a variety of rotation axis, it is impossible to avoid a discrepancy between the clinical definition and any mathematical convention.

Thus, interpretation of joint motion is only possible in combination with the underlying methodology. Therefore, we are sure that we are describing effective joint motion, but this is based on the upper problem of definition not always consistent with the clinical understandings of the three angular components.

The definitions of the joint coordinate systems were added to the supplementary materials.

Furthermore, we have added the following limitation: “Another limitation of this study is, that the here used marker set has not been directly validated with a gold standard such as MRI. “

And in the conclusions:” However, the higher complexity of the combined movements needs more cautious interpretation due to gimbal lock, limited clinical interpretability and dependency of resulting joint motion on the choice of mathematical convention for joint angular description.”

Results: Please provide either a written summary or table that gives the fixed and random effects coefficients for the mixed linear model used. E.g. Beta and standard error, OR confidence intervals, OR t-statistic for fixed effects tested, as indicated you used a linear mixed model.

The following sentence has been added to the results section:
The fixed and random effects coefficients of the linear mixed model are included in the supplementary material section (Supplementary Table 2-4).

And the requested tables were included as supplementary material.

Minor concerns/ comments:

Abstract -

At the end of the background information, a statement of aims could be helpful, as could the addition of some summary data into the results summary.

The following statement of aims has been added to the end of the background information.

“Therefore, the aim of the study was to examine upper extremity kinetics and kinematics in 3D of the internal and external rotation exercises.”

Final concluding sentence should be reworded.

The last sentence of the abstract has be reworded to this:

“Therefore, the loading motion patterns identified in this study can help to choose suitable shoulder exercises dependent on the training objective.”

Introduction -

-Generally the introduction is clear and well written. The final sentence regarding aims would benefit from having a number of smaller cleaner and more direct sentences.

This part has been partially rewritten and enhanced to: With the aim to establish exercise regimes that are able to provide high joint moments throughout a large rotational RoM for the rotator cuff muscles, the goal of the present study was therefore to examine upper extremity kinetics and kinematics in 3D for five internal and five external rotation exercises. All exercises are performed using two types of force application methods, including constant and elastic resistance. The second goal of the present study was to design a marker set for functional joint centre determination of the shoulder joints to be able to examine upper extremity kinetics and kinematics in 3D of the selected shoulder strength exercises. The range of motion between the two types of force application, constant and elastic resistance, is expected to show no difference. However, the maximal moments observed, as well as the angles of the maximal moments are assumed to differ between the selected exercises.

-Did the authors have any hypotheses?
This hypotheses statement was added to the end of the introduction

The range of motion between the two types of force application, constant and elastic resistance, is expected to show no difference. However, the maximal moments observed, as well as the angles of the maximal moments are assumed to differ between the selected exercises.

And in the discussion section further sentences were complemented and added.

Therefore, as expected in the first part of our hypothesis, the RoM did not differ significantly between the two resistance types. Importantly, however, the maximum internal/external rotation moment, as significantly higher with CR than with ER. The second hypothesis, assuming a difference of Mmax and α(Mmax) for the different exercises has been confirmed.

Methods -

-I request that the authors add a statement to the paper confirming whether, for all experiments, they have reported all measures, conditions, data exclusions, and how they determined their sample sizes. The authors should, of course, add any additional text to ensure the statement is accurate. This is the standard reviewer disclosure request endorsed by the Center for Open Science [see http://osf.io/hadz3]. I include it in every review.

The following sentence has been inserted at the end of the first “Procedures” paragraph:

No filtering or gap filling was applied to the marker trajectories during the post processing.

And in the last paragraph also this statement has been inserted:

All valid trials were analysed and no outliers were removed from the evaluation of the measured data.

- Can you please indicate how handedness was assessed or dominance determined? Preference for coordination based tasks does not always align with strength dominance, so it is important to provide this detail within the methods to allow any study replication.

The dominant arm was selected by the participants themselves, after the by asking for the preferred arm for throwing tasks.

The sentence reads now:

“All participants performed eight repetitions of ten exercises using their dominant arm for coordination-based tasks, for which arm position and direction of the external force was varied (Figure 1).”
- Experimental approach - line 30. I think it would benefit from breaking this sentence up and more clearly indicating that the exercises are visualized in Figure 1. As is, the reference to the figure is less clear.

The reference has been moved to the end of the next sentence.

Five of the exercises are designed to train the internal rotator muscles of the shoulder (Elb_int, Elb20_int, Sho_int, Sho20_int, Sho20_com), and five the external rotator muscles (Elb_ext, Elb20_ext, Sho_ext, Sho20_ext, Elb20_com) (Figure 1).

- Line 48 - this was the typical range of load used in rehab - citation?

The load used in rehabilitation would be very injury dependent and also dependent on the individual strength level needed by the patient during daily living or working activities.

In order to prevent fatigue during the exercise the selected load was lower compared to the previous work (17).

Procedures

- An indication of the filtering of the load cell given - but no indication on treatment of vicon data. filtering method, cut-off freq?

No filtering or gap filling was applied to the marker trajectories during the post processing.

- Supplementary Figure 1 would be helpful in the main document, rather than supplementary. Unless there is a limit on figures, I would put this there.

As suggested the supplementary Figure 1 has been included into the main document as Figure 2 and the former Figure 2 has been changed to Figure 3.

- Supplementary Figure 2 - If there is a way to simplify this skeleton into a line image (with the marker set overlay), it will help the clarity. The current grey scale shading makes it hard to read some of the things written over the chest area.

The color of the joint coordinate system has been changed, as well as the grey scale skeleton has been lightened for better visibility of the markers and JCS.

- Line 52, and Line 1 and 10 (following page) currently reference the wrong sup. figure.

Corrected

- Can the authors please provide more information with regards to the use of a Bonferroni correction in their analysis? i.e. what was the p-value corrected by?
The following has been added to the manuscript:” Bonferroni-corrected post-hoc tests were conducted where appropriate using factor 6 according to the parameter examined (p=.00833).”

Results -

- Please insert table reference in first sentence.

All parameters are displayed as mean ± standard deviation. Positive values correspond to internal rotation, adduction, or flexion angles or moments (Table 1, Table 2).

- In your statistical methods section, you do not mention about analysis of SCJC, which then confused me with lines 20 to 28 (under kinematics results). If the authors see these results are relevant, then this analysis should be indicated in the stats-methods.

All parameters for the GHJC were statistically evaluated around the internal/external (eGH3) and the adduction/abduction (eGH2) rotation axis. A statistical analysis of the SCJC was not performed.

- Table 1 and 2 are comprehensive, but I believe in the need for p-values for all statistical tests to be presented (not just highlighted as p<0.05). I would suggest for the actual p-value per contrast (exception of p<0.001 listed as that) to be entered in the section of exercise comparisons.

The internal/external rotation angle at which the maximal moment Mmax occurred, α(Mmax), was significantly different between the two resistance types for all exercises except for Sho_int (p=0.396) and Sho20_int (p=0.794) (Tables 1&2).

The adduction/abduction angle, α(Mmax), was not significantly different between CR and ER (internal and external rotational exercises p=0.935 and p=0.919, respectively) (Tables 1&2).

Conclusion -

- Caution should be indicated on the results relating to the combined movements based on motion capture limitations for these movements

A sentence, which highlights the limitation of the combined movements, has been added to the conclusion.

However, the higher complexity of the combined movements needs more cautious interpretation due to gimbal lock, limited clinical interpretability and dependency of resulting joint motion on the choice of mathematical convention for joint angular description.