**Running title:**

Multilevel Regression Modeling as a Complement to Traditional Repeated Measures Analysis of Variance in Sports Biomechanics Research

**Abstract:**

Multilevel modeling is a powerful, flexible, yet neglected analysis method in the sports biomechanics literature. In this paper, we hope to draw increased attention to this underused research tool and lobby for its increased adaptation when examining repeated measures biomechanics data. First, we introduce the rationale and approach underlying multilevel regression models. We then use simulated and real-world data to illustrate their potential application in sports biomechanics research. Lastly, we provide some recommendations, words of caution, and additional resources.

**Paper Outline:**

1. **General Intro**

* Biomechanists throw a lot of data away via discretization and ensemble averaging
* Statistical parametric mapping can help with discretization but what about instances where looking at discrete values is warranted?
* There are still methodological improvements available that can help us better understand our data and ask richer/deeper research questions.
* Current use of multilevel models in sport biomech is limited to two papers (as far as I can tell)

Purpose statement:

* Therefore, our purpose is to introduce multilevel regression modeling to a sports biomechanics audience and offer a brief tutorial on model notation, construction, and interpretation. We also outline the advantages and disadvantages of multilevel models over traditional repeated measures designs and offer recommendations for those interested in further exploration of multilevel techniques.

1. **Intro to “normal” regression**

* “Ease the reader in” to a methods paper
  + Reminder of slopes/intercepts/residuals
  + Introduce “less overwhelming” model notion
* Simple regression scatterplot figure

1. **Intro to multilevel regression**

* Upgrade model notation
* Incorporate simulated figures

1. **Multilevel regression example(s)**

* One example from dissertation data or one from dissertation + one from quant psych?
* Could sell as “here’s our first example from quant psych where multilevel models and theory are much more established and then here’s a second example specific to sport biomech”

1. **Benefits and limitations of multilevel models**

* Three primary benefits of MLM over traditional repeated measures as related to sport biomech
  + Case completeness: can handle missing data
  + Temporal flexibility: time (or whatever is on the x-axis) doesn’t have to be equally spaced for everyone)
  + Design balance: can handle different number of repeated measures for different participants
  + Others? Different “most important” ones?
* Limitations of MLM compared to traditional repeated measures as related to sport biomech
  + Larger samples sometimes required (depends on research question)
  + Increased interpretive difficulty
* When is normal repeated measures just fine?
  + I don’t want the paper to come off as “repeated measures is total crap and anyone who has ever run a RMANOVA is dumb”. I think a section outlining when traditional repeated measures works fine (and would be preferred over an overly complicated technique) would help that
    - Pre/post or maybe pre/post/follow up designs
      * Once you get beyond 3 repeated measures, c’mon…use some kind of longitudinal MLM
    - No missing data with same number of observations per participant
    - Only linear relationships are of interest and make theoretical sense
* Table could be powerful here

1. **Recommendations for further reading**

* Hox book
* What others?

Chart, scatter chart

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Figure 1: Hypothetical simple regression

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Figure 2: Fictional multilevel model with random intercepts. Individual regression lines are parallel (equal slopes) but differ in their respective intercepts

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Figure 3: Fictional multilevel model with random slopes. Individual regression lines are not parallel (unequal slopes) but share a mutual intercept

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Figure 4: Fictional multilevel model with random intercepts and slopes. Individual regression lines are not parallel and do not share a mutual intercept