# Electromyography Normalization Error in Drop Jump Landings

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## BACKGROUND

- Electromyography (EMG) is commonly used to measure muscle activity in lower extremity movements (i.e., jumping, landing, cutting).
- Unfortunately, EMG presents its units on an arbitrary scale measured in voltage.
- Therefore, to interpret EMG amplitude between individuals, normalization must occur.
  - EMG amplitude is expressed as a percentage of the reference value obtained through maximal voluntary isometric contraction (MVIC), maximum value measured during dynamic activity, or M-wave max amplitude.
- In lower extremity movement research, there is no standardized approach to EMG normalization.
- MVIC normalized to EMG amplitude may underrepresent maximum activity observed during the activity (9). These supramaximal values may occur for various reasons: recorded MVIC body position, physical strength of participant, contraction type, researcher experience with MVIC process, peak extraction or muscle crosstalk.
- Researchers' systematic review (January 2018 – 2023) of 129 studies, found greater than 100% activation in 29 studies (60.40%) and 17 studies (35.40%) did not report sufficient procedures when supramaximal values were found when using MVIC normalization. Only 2 studies (4.1%) did not report supramaximal activation.
- We hypothesized that a MVIC will underestimate muscle activity across all muscles in a drop jump landing.

## METHODS

- Single group measure study: Exclusion criteria were any surgical repair or injury which prevented physical activity participation for < 4 weeks, acute pain, or diagnosed neurological condition affecting motor performance.
- Dependent variable: max %MVC during drop jump compared to 100% activity maximum for each muscle.
- Independent variable: normalization method, MVIC, activity max.
- Table 2: EMG electrodes placement and MVIC descriptions (4 , 6).
  - MVICs were randomized, 3 maximal trials, 2-minutes rest
- Drop jump procedures: (verbally explained and visually demonstrated)
  - 30cm high box was placed at 50% of the participants height from the back edge of two force plates.
    - Participants were instructed to jump from the box so that one foot would land on each force plate. Then jump as high and explosively into the air with both feet landing back on each force plate.
    - Practice attempts ensured movement quality.
    - 10 successful attempts were then recorded.
- Normalization procedures:
  - Using the highest value from three MVIC trials to represent EMG data recorded during the drop jump as %MVIC.
  - Using the highest value recorded from the 10 drop jump trials to represent the EMG data as activity max %.
- One-sample t-test was used to compare maximum values recorded during the drop jump normalized to %MVIC to a set value of 100% for each muscle.
  - If using maximum activity value to normalize EMG, the highest recorded value would be 100%, since it was recorded during activity.
  - All comparisons were Wilcoxon Ranked Sign Test to confirm significant observations, due to potential of outliers.

## Drop jump **normalization error** is **substantial** and **contributes to high variability** observed **in activation between participants** and **different muscle groups**

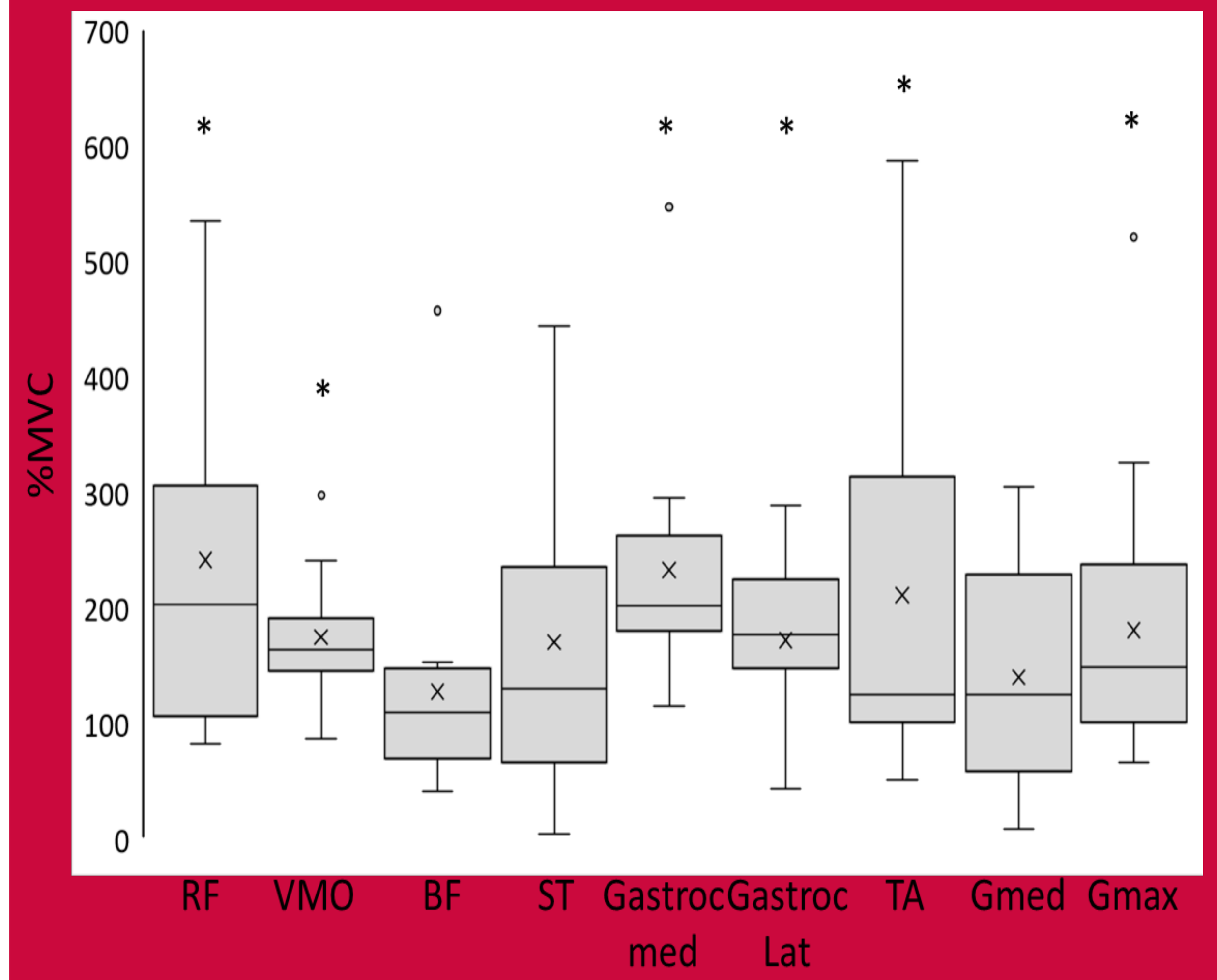


Figure 1: Spread of maximum EMG amplitude measured during the drop jump and normalized to MVIC.

*Significantly different from 100% normalized activity max, circles are outliers > 1.5x the interquartile range, x indicates mean, and center line is the median.

**TABLE 1. Participant Characteristics**

| Descriptive Data | |
|---|---|
| N (M,W) | 16 (10, 6) |
| Age (Years) | 23 ± 1 |
| Height (cm) | 173 ± 10 |
| Body Mass (kg) | 40 ± 14 |

Values are mean±SD.

**TABLE 2. MVIC Position**

| Muscle | MVIC Test Position | Reference |
|---|---|---|
| Gluteus Maximus | Lying prone, knee flexed 90 degrees. | Contreras et al., 2015 |
| Gluteus Medius | Side lying contralateral from tested side | Bernard et al., 2017 |
| Rectus Femoris | Seated, hip & knee flexed to 90 degrees | Purkayastha et al., 2006 |
| Vastus Medialis | Seated, hip & knee flexed to 90 degrees | Purkayastha et al., 2006 |
| Semitendinosus | Prone, knee flexed to 60 degrees | Hsu et al., 2006 |
| Biceps Femoris | Prone, knee flexed to 60 degrees | Hsu et al., 2006 |
| Tibialis Anterior | Seated, hip & knee flexed to 90 degrees, ankle neutral | de Oliveira Sousa et al., 2007 |
| Medial & Lateral Gastrocnemius | Seated knee flexed to 30 degrees, dorsiflexed 15 degrees | Albertus-Kajee et al., 2011 |

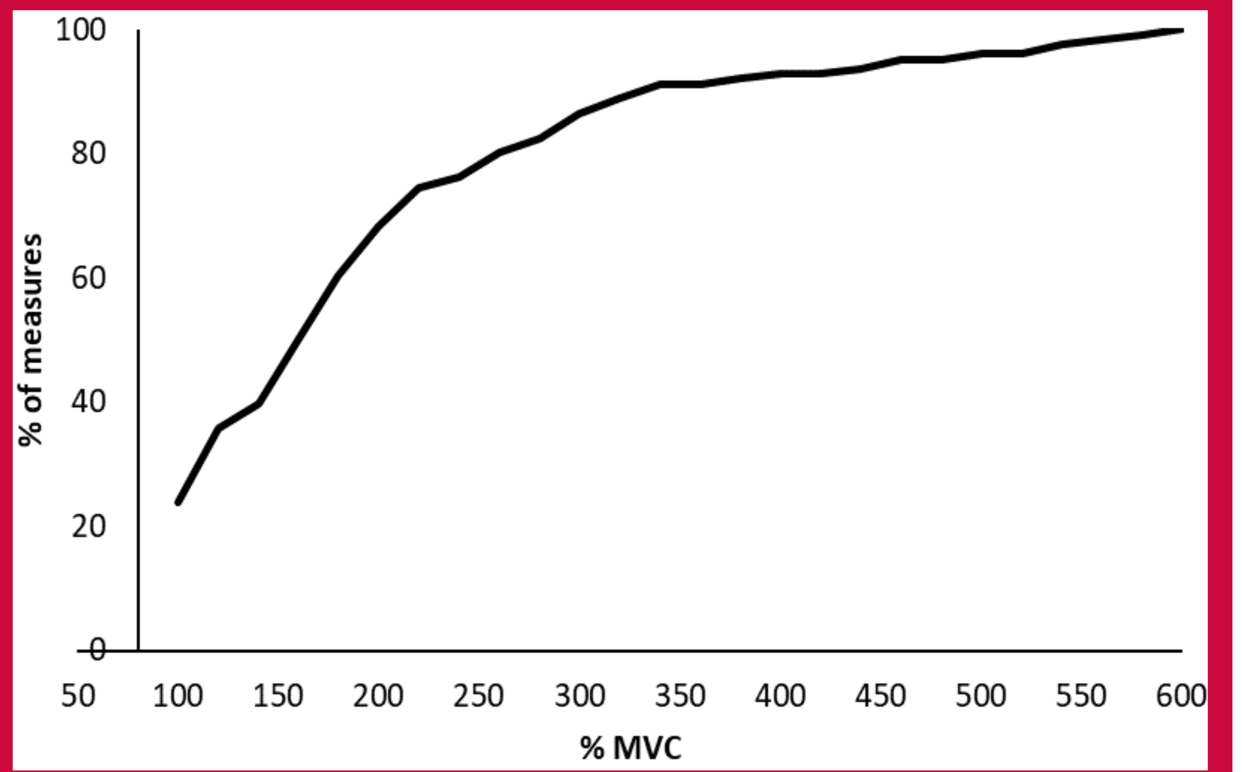


Figure 2: % number of measures below a %MVC threshold. Dashed lines highlight that 20% of all measures were greater than 260% MVC.

## RESULTS

- A significant difference from 100% activity max was observed for %MVIC for six out of the nine muscles (Figure 1).
  - The rectus femoris ($M$ = 241 ± 140%, $p$ = .002), the vastus medialis ($M$ = 174 ± 50%, $p$ < .001), the medial gastrocnemius ($M$ = 232 ± 111%, $p$ = .002), the lateral gastrocnemius ($M$ = 171 ± 73%, $p$ = .002), the tibialis anterior ($M$ = 210 ± 172%, $p$ = .021), and the gluteus maximus ($M$ = 180 ± 125%, $p$ = .027) with these observations confirmed with the one sample Wilcoxon ranked sign test.
  - The differences were not significant for the biceps femoris ($M$ = 127±105%, $p$ = .370), the semitendinosus ($M$ = 170 ± 145%, $p$ < .120), or the gluteus medius ($M$ = 139 ± 100%, $p$ < .180).

## CONCLUSIONS

- An effective MVIC would be one which elicits near maximum value as measured during the LE activity.
  - Values greater than 100% indicate that EMG amplitude recorded during activity was greater than max. during MVIC.
    - Statistically true for six out of nine muscles.
      - Similar research identified increased amplitude from jumping than MVICs in TA (9).
  - Only 23% of maximum activity recorded across all muscles was < 100% (Figure 2).
    - Of concern, statistical significance does not complete the picture.
      - On average MVICs underestimated maximal activity by 71-140%. With 20% of our measures having an error of 160% or greater relative to MVIC.
- Our systematic review revealed 60.40% of studies using MVIC normalization had supramaximal activation.
  - No one author addresses how supramaximal activation affected statistical outcome or data interpretation.
    - This is problematic when comparing between muscles.
      - Quadriceps to hamstrings activation ratio.
        - An MVIC which underestimates activation potential of a muscle may be incorrectly interpreted as a muscle which is being activated to its maximum potential during a motion.

## PRACTICAL APPLICATIONS

- A between subject comparison or between muscle comparison using values normalized to MVIC may not be appropriate.
- Researchers need be aware of the error between MVIC and maximum activity elicited during the movement.
  - Important for correct interpretation of EMG amplitude data.
    - Assist researchers in future studies.

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