Muscular Fatigue Influences Motor Synergies During Push-Ups

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Introduction

- The conventional push-up is a popular exercise used to test human muscular endurance.[1, 2]
- Whole body movement requires changes in the ground reaction forces (GRF) generated at each point of contact (arms and feet) with the ground.
- Changes in GRF are achieved through muscular contractions mostly at the triceps brachii and pectoralis major.[3]
- The motor control mechanisms used in this motion are relatively unknown and adaptations after fatigue have not been quantified.

Purpose: This preliminary investigation aimed to determine whether humans adjust individual limb forces (push-up synergies) as they near volitional fatigue.

Hypothesis: Muscular fatigue reduces the between-arm synergy in vertical GRF production.

Methods

- 21 volunteers participated in a single motion capture trial.
- Participants were instructed to arrange themselves in a plank position with each extremity within the bounds of an embedded force platform (Figure 1).
- They performed as many push-ups as possible in one trial:
  - stopped at self-determined failure
  - completed down, up, hold plank movements
  - at a rate of 50bpm
- Force data was collected at a frequency of 1000Hz.
- An index of synergy, defined as correlations between vertical forces was calculated for every downward and upward motion within the push-up trial :

$$SYN_{\text{arms}} = \frac{\sum_{j\neq i}^{n} \text{corr}(\text{vGRF}_{Left\ Hand}, \text{vGRF}_{Right\ Hand})}{2} \quad [1]$$

- A Pearson correlation test was used to determine if the slope of the line of best fit (ΔSYNarms / Δ% Trial) was significantly ($p \leq 0.05$) different than zero.

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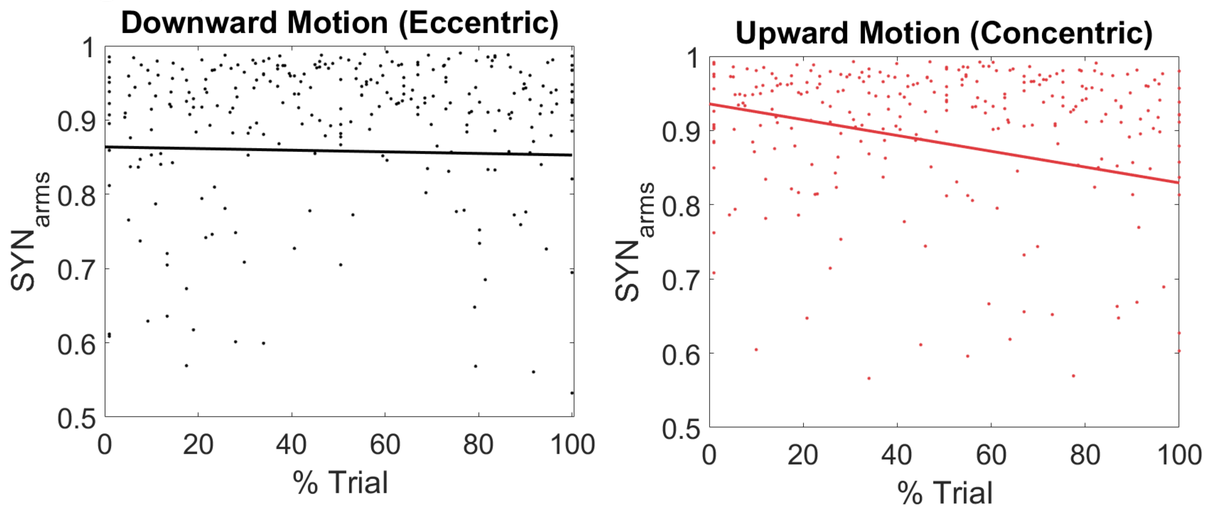
Results

- Between-arm vertical forces were positively correlated during upward and downward motion.
  - SYNarms > 0
- Upward limb synergy (red line, Figure 2) significantly ($p < 0.01$) decreased as participants neared volitional fatigue (100% trial).
- Downward limb synergy did not change ($p = 0.77$) as participants neared volitional fatigue (black line, Figure 2).

Figure 1. Example of participant orientation on the four force plates (blue squares)



$Y_{down} = 0.0001*x+0.86$ ($p = 0.77$) $Y_{up} = 0.0011*x+0.94$ ($p * < 0.01$)

Figure 2. Index of synergy (SYN_{arms}) measures for each push-up from all participants during downward motion (black) and upward motion (red). The lines of best fit represent average changes in between-arm synergy as participants near volitional fatigue (100% trial).

Conclusions

- Positive correlation for most push-ups indicate that limbs worked together to produce increases or decreases in vGRF.
- Muscular fatigue reduced the synergistic actions between limbs in upward motion, when the participant was using concentric muscle contractions to move the body.
- Fatigue produced no change in arm synergy during downward motion when the participant was utilizing eccentric muscle contractions.

Public Health Significance: This research is the first to investigate how the central nervous system adapts to perform motor tasks after muscular fatigue. This knowledge may be for the reduction of fatigue related injury risks.

References

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3. Youdas JW, et al. J Strength Cond Res. **24**.12 (2010): 3352-62.

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