PEAK YANK'S CONTRIBUTION TO JUMP HEIGHT DIFFERS BETWEEN COUNTERMOVEMENT JUMPS WITH AND WITHOUT ARM SWING

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Introduction

The countermovement jump (CMJ) is often used to assess lower body power through force-time data analysis. Variables including mean rate of force development (RFD) (3) and peak ground reaction force (GRF) (5) have been identified as significant predictors of CMJ performance. Recently, yank, the 1st derivative of force ($N \cdot s^{-1}$) representing instantaneous, or peak, RFD, has been suggested to influence jump height (JH) (4). The magnitude of yank is suggested to positively influence JH by increasing force magnitude and decreasing jump duration, leading to greater RFD (4). Further, previous work has identified differences in CMJ performance between CMJs with and without arm swing (6). How yank influences CMJ performance in jumps with and without arm swing is less explored.

Purpose

The purpose of this study was to assess the relationship between peak yank (PY) and CMJ performance with and without arm swing in recreationally trained jumpers.

Methods and Materials

- Recreationally active males (n=5) and females (n=3) (n=8, X±SD, age=19.8±0.5 yrs., height=166.2±16.7 cm, mass=74.1±13.7 kg) participated in this study.
- Participants completed six maximal CMJs: three with (CMJ-AS) and three without arm swing (CMJ-NAS). The CMJ for each condition with the greatest flight time (FT) was retained for analysis. Participants rested at least 2 minutes between CMJs. All CMJs were performed on a uniaxial force plate sampling at 1000 Hz.
- Mean and peak forces during the braking (the point on the force-time curve where body mass is reached to where center of mass velocity reaches zero) and propulsive phases (starting at the end of braking and ending at take-off) were analyzed. JH was calculated from FT. Yank-time data was derived from force-time data using a low-pass Hamming filter with a 10 Hz cutoff frequency.
- Paired samples t-tests compared performance between CMJs with and without arm swing for the following metrics: PY, JH, FT, modified reactive strength index (RSImod) mean (MBF) and peak braking force (PBF), mean (MPF) and peak propulsive force (PPF), and durations of the braking (BPD) and propulsive phases (PPD). Hedges' g effect sizes assessed magnitude of effect. Pearson product-moment correlations assessed the relationship between PY and other jump metrics in both conditions ($p<0.05$).

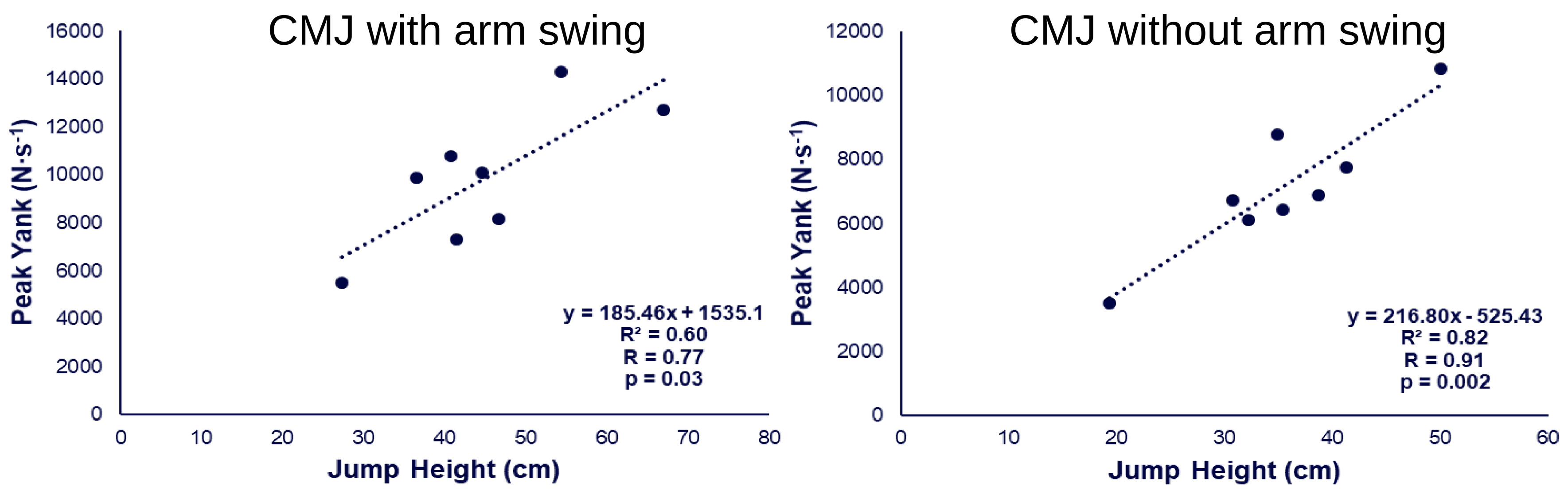

Figure 1. Scatterplots with linear lines of best fit, regression equations, R^2, R, and p values to assess the influence of peak yank on jump height in countermovement jumps with (left) and without (right) arm swing.

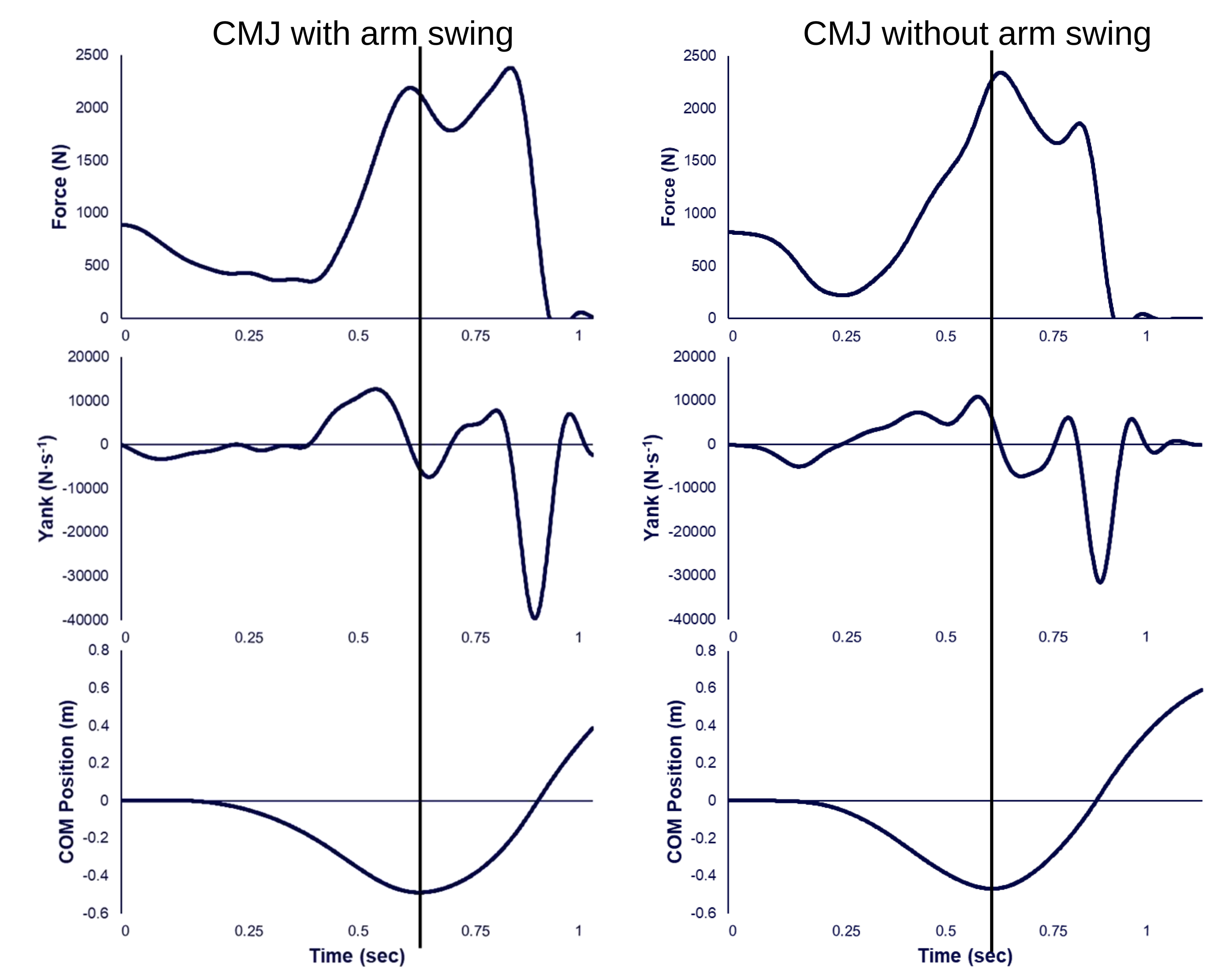

Figure 2. Representative countermovement jump force-time (top), yank-time (middle) and center of mass (COM) position-time curves for a jump with (left) and without (right) arm swing.

Variable	CMJ-AS	CMJ-NAS	p	ES
Jump Height (cm)	44.82 ± 11.89	35.31 ± 8.87	<0.001	2.43
Time to Takeoff (sec)	0.99 ± 0.11	0.97 ± 0.10	0.53	0.22
RSImod ($m \cdot s^{-1}$)	0.46 ± 0.13	0.35 ± 0.09	0.001	1.70
Flight Time (sec)	0.60 ± 0.08	0.53 ± 0.07	<0.001	3.36
Peak Yank ($N \cdot s^{-1}$)	9848.13 ± 2854.71	7130.4 ± 2125.61	0.02	1.07
Mean Braking Force (N)	1099.64 ± 280.47	1133.32 ± 216.69	0.47	0.26
Peak Braking Force (N)	1579.54 ± 411.28	1549.37 ± 385.75	0.64	0.16
Braking Phase Duration (sec)	0.26 ± 0.08	0.23 ± 0.03	0.21	0.46
Mean Propulsive Force (N)	1395.79 ± 362.33	1335.72 ± 323.03	0.02	1.04
Peak Propulsive Force (N)	1928.92 ± 464.66	1696.24 ± 417.06	0.004	1.44
Propulsive Phase Duration (sec)	0.34 ± 0.04	0.33 ± 0.03	0.26	0.29

Table 1. Performance data for jumps with (CMJ-AS) and without arm swing (CMJ-NAS). Data are presented as $\overline{X}$ ± SD. Hedges' g effect sizes (ES) are displayed.

Results

Comparisons between CMJ-AS and CMJ-NAS is on table 1

- Greater JH, PY, RSImod, FT, and propulsive forces in CMJ-AS (p = <.001-002, g = 1.04-3.36).
- Braking forces or jump durations were not different between jumps (p = 0.21-0.64, g = 0.16-0.46).

Contributions to jump height

- PY contributed more to JH in CMJ-NAS (p = 0.002, r = 0.91) than CMJ-AS (p = 0.03, r = 0.77) (**fig. 1**).
- In CMJ-AS, MBF, PBF, MPF, and PPF were stronger predictors of JH (p = 0.01, r = 0.83-0.85).
- Strong correlations between JH and forces were also observed in CMJ-NAS (p = 0.002-0.02, r = 0.81-0.91).

Conclusion

Despite smaller PY magnitude, PY contributed to JH more in CMJ-NAS. This may be due to arm swing's influence on CMJ performance. In CMJ-AS, greater GRFs were seen, with GRFs predicting JH more than PY. Previous work indicates arm swing's contribution to greater GRFs (6), with peak GRF being a strong predictor of JH (5). In the current study, jump durations were similar between conditions. However, CMJs with arm swing may have longer ground contact times (6) and greater time to takeoff (1). Higher forces and/or longer time to apply forces may lead to greater impulse, influencing jump performance. As GRFs are significantly reduced when removing arm swing, other metrics, like PY, may contribute to JH to a greater degree. Depth was not assessed in the current study, though previous work suggests CMJ-AS have greater depth (2). As depth was self-selected, similar jump durations may be due to differences in depth.

Practical Application

PY and GRFs were strong predictors of JH, though their contributions differed between jump types. As arm swing influences what metrics most contributes to JH, this information can be used in testing and programming CMJs. If improved JH is desired, training may be implemented to influence the metric that most influences JH in a sport-specific manner.

References

1. Cabarkapa, D, Philipp, N, Cabarkapa, D, Eserhaut, D, and Fry, A. Comparison of force-time metrics between countermovement vertical jump with and without an arm swing in professional male basketball players. Int J Strength Cond 3, 2023.
2. Donahue, PT, McInnis, AK, Williams, MK, and White, J. Examination of countermovement jump performance changes in collegiate female volleyball in fatigued conditions. J Funct Morphol Kinesiol 8: 137, 2023.
3. Laffaye, G and Wagner, P. Eccentric rate of force development determines jumping performance. *Comput Methods Biomech Biomed Engin* 16: 82–83, 2013.
4. Lin, DC, McGowan, CP, Blum, KP, and Ting, LH. Yank: the time derivative of force is an important biomechanical variable in sensorimotor systems. *J Exp Biol* 222: jeb180414, 2019.
5. Miller, JD, Fry, AC, Ciccone, AB, and Poggio, J. Analysis of rate of force development as a vertical jump height predictor. *Res Q Exerc Sport* 94: 638–645, 2023.
6. Mosier, EM, Fry, AC, and Lane, MT. Kinetic contributions of the upper limbs during counter-movement vertical jumps with and without arm swing. *J Strength Cond Res* 33: 2066, 2019.

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