The Effect of Load Placement on Force, Velocity, and Power Production During a Countermovement Jump

Nicole Bordelon, Devin Jones, Kael Sweeney, Daniel Davis, Meghan Critchley, LuAnna Rochelle, Ana George, and Boyi Dai

Division of Kinesiology & Health, University of Wyoming, Laramie, WY, U.S.A.

ABSTRACT

Introduction: Muscular power training is essential for sport performance programs [2, 3]. Weighted jumps are a potential approach, however, optimal load magnitudes and placements should be considered [1]. Although weighted jumps are frequently performed with a barbell placed on the shoulders, constraining the arms to stabilize the barbell may decrease their contribution to force and power production [1]. The purpose was to examine the effects of load placement on force, velocity, and power during a countermovement vertical jump (CMVJ). **Methods:** A total of 21 recreationally training athletes (9 males and 12 females; age: 22.0± 2.4 y; height: 1.75 ± 0.10 m; mass: 69.6 ± 12.3 kg) with prior experience in jumping completed the study. Participants completed seven CMVJ conditions in a random order (No Load, 10 and 20% Barbell on shoulders, 10 and 20% weighted Vest, and 10 and 20% Dumbbell) with loading percentages relative to body weight. Kinematic and force data were collected. Power was calculated as the product of whole-body vertical forces and whole-body center of mass vertical velocities. Vertical forces were calculated as the whole-body mass times the sum of its vertical acceleration and gravity. Segment contribution to whole-body forces were calculated as the mass of the segment times the sum of its vertical acceleration and gravity. Segment velocity was calculated as the mass of the segment times its vertical velocity and divided by the whole-body mass Jump height (JH), peak power (PP) in the concentric phase, whole-body forces and velocities at PP, and segment contribution to forces and velocities at PP were compared among the seven conditions using paired t-tests (0.05). **Results**: The No Load and 10% Dumbbell conditions resulted in the greatest JH and velocities at PP. Forces at PP were greater in the two Dumbbell and 20% Vest conditions compared to No Load. The two Barbell conditions generally demonstrated the least jump height, PP, forces, and velocities at PP. The No Load and two Dumbbell conditions had the greatest trunk and leg forces. The greatest arm forces were observed in the 20% Dumbbell condition followed by 10% Dumbbell. The 20% Vest produced the greatest external load forces. Segmental velocities for the trunk and arms were generally the greatest leg velocities. The greatest external load velocity was observed in the 20% Dumbbell condition. **Conclusion**: The 10% Dumbbell condition appeared to be the most optimal body-weight percentage and load placement for power production. The increased PP resulted from a greater force production mainly due to the arms and external load, whilst not drastically decreasing movement velocities. Although the 10% Dumbbell condition had decreased segment velocities compared to No Load, the decreases were compensated by the increased velocities of the external load. **Practical Application**: The current findings suggest performing CMVJs with 10% body weight of dumbbells and arm swing may be considered when seeking to maximize power production.

PURPOSE

- Muscular power training is essential for sport performance programs [2, 3].
- Weighted jumps are a potential approach, however, optimal load magnitudes and placements should be considered [1].
- Although weighted jumps are frequently performed with a barbell placed on the shoulders, constraining the arms to stabilize the barbell may decrease their contribution to force and power production [1].
- **The purpose was to examine the effects of load placement on force, velocity, and power during a countermovement vertical jump (CMVJ)**.

METHODS

- A total of 21 recreationally training athletes (9 males and 12 females; age: 22.0± 2.4 y; height: 1.75 ± 0.10 m; mass: 69.6 ± 12.3 kg) with prior experience in jumping completed the study.
- Participants completed seven CMVJ conditions in a random order (**No Load, 10 and 20% Barbell on shoulders, 10 and 20% weighted Vest, and 10 and 20% Dumbbell**) with loading percentages relative to body weight (**Figure 1 a, b, c**). Kinematic and force data were collected.
- Power was calculated as the product of whole-body vertical forces and whole-body center of mass vertical velocities. Vertical forces were calculated as the whole-body mass times the sum of its vertical acceleration and gravity.
- Segment contribution to whole-body forces were calculated as the mass of the segment times the sum of its vertical acceleration and gravity **(Figure 2 a)**. Segment velocity was calculated as the mass of the segment times its vertical velocity and divided by the whole-body mass **(Figure 2 b)**.
- Jump height (JH), peak power (PP) in the concentric phase, whole-body forces and velocities at PP, and segment contribution to forces and velocities at PP were compared among the seven conditions using paired t-tests (0.05).

Figure 1a. CMVJ with a barbell on shoulders

Figure 1b. CMVJ with a vest

Figure 1c. CMVJ with dumbbells

RESULTS

- The No Load and 10% DB conditions resulted in the greatest JH and velocities at PP. Forces at PP were greater in the two DB and 20% Vest conditions compared to No Load. The two BB conditions generally demonstrated the least jump height, PP, forces, and velocities at PP (Table 1).
- The No Load and two DB conditions had the greatest trunk and leg forces. The greatest arm forces were observed in the 20% DB condition followed by 10% DB. The 20% Vest produced the greatest external load forces. Segmental velocities for the trunk and arms were generally the greatest leg velocities. The greatest external load velocity was observed in the 20% DB condition.

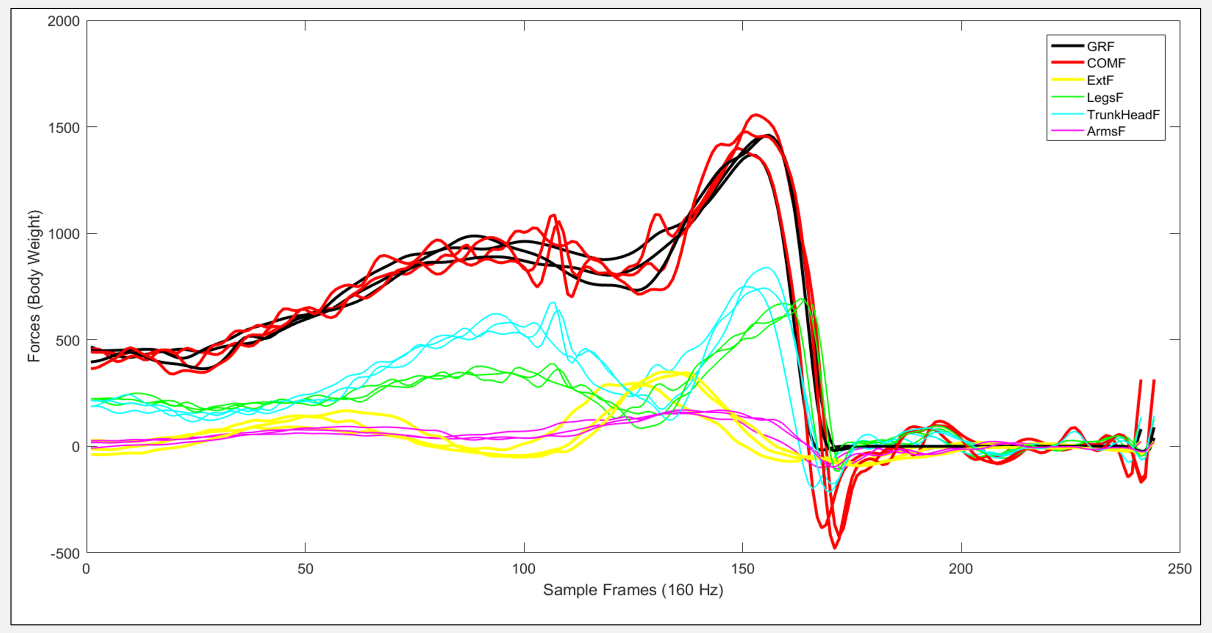

Figure 2a. Segment forces during a countermovement jump trial

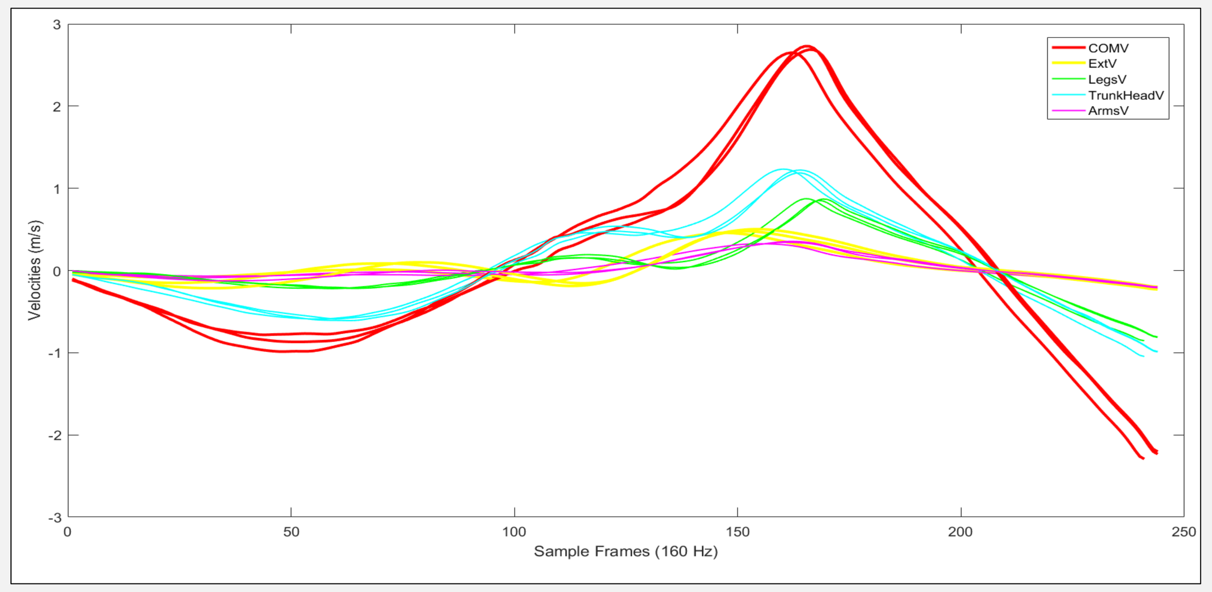

Figure 2b. Segment velocities during a countermovement jump trial

RESULTS

Table 1. Mean ± standard deviations of dependent variables among different jumping conditions

	No Load	10% Barbell	20% Barbell	10% Vest	20% Vest	10% Dumbbell	20% Dumbbell
Jump Height (m)	0.41 ± 0.09 A	0.36 ± 0.06 D	0.37 ± 0.06 C	0.39 ± 0.08 B	0.38 ± 0.07 BC	0.42 ± 0.09 A	0.37 ± 0.09 CD
Peak Power (w/body weight)	5.42 ± 1.14 BC	4.66 ± 0.68 D	4.64 ± 0.75 D	5.35 ± 1.06 C	5.26 ± 1.02 C	5.73 ± 1.10 A	5.63 ± 1.12 AB
Forces at Peak Power (body weight)	2.25 ± 0.34 C	2.14 ± 0.18 D	2.22 ± 0.17 C	2.31 ± 0.28 C	2.38 ± 0.27 B	2.37 ± 0.26 B	2.48 ± 0.25 A
Velocities at Peak Power (m/s)	2.41 ± 0.28 A	2.17 ± 0.21 C	2.08 ± 0.23 D	2.31 ± 0.27 B	2.20 ± 0.26 C	2.40 ± 0.30 A	2.26 ± 0.30 B
Segment Contribution to Forces at Peak Power (body weight)							
Trunk	1.19 ± 0.26 A	0.89 ± 0.09 C	0.87 ± 0.07 D	1.10 ± 0.19 B	1.05 ± 0.20 B	1.15 ± 0.18 A	1.10 ± 0.15 AB
Legs	1.11 ± 0.11 A	0.98 ± 0.09 D	0.93 ± 0.10 E	1.05 ± 0.11 B	0.99 ± 0.09 CD	1.06 ± 0.09 B	1.01 ± 0.09 C
Arms	-0.05 ± 0.10 C	0.13 ± 0.03 B	0.13 ± 0.02 B	-0.08 ± 0.08 C	-0.07 ± 0.06 C	0.12 ± 0.05 B	0.15 ± 0.03 A
External Load	0 ± 0 F	0.14 ± 0.02 D	0.29 ± 0.03 B	0.25 ± 0.05 C	0.41 ± 00.7 A	0.04 ± 0.07 E	0.22 ± 0.10 C
Segment Contribution to Velocities at Peak Power (m/s)							
Trunk	1.35 ± 0.16 A	1.13 ± 0.13 B	0.97 ± 0.12 D	1.14 ± 0.14 B	1.00 ± 0.12 C	1.13 ± 0.13 B	0.97 ± 0.12 D
Legs	0.63 ± 0.09 A	0.57 ± 0.05 B	0.50 ± 0.04 D	0.56 ± 0.05 BC	0.49 ± 0.05 DE	0.55 ± 0.06 C	0.48 ± 0.05 E
Arms	0.42 ± 0.12 A	0.22 ± 0.03 D	0.19 ± 0.03 E	0.34 ± 0.09 B	0.29 ± 0.08 C	0.30 ± 0.06 C	0.22 ± 0.04 D
External Load	0 ± 0 E	0.25 ± 0.03 D	0.42 ± 0.06 B	0.27 ± 0.03 C	0.42 ± 0.05 B	0.42 ± 0.11 B	0.59 ± 0.16 A

Note: The effect of jumping condition is grouped, where A > B > C > D > E > F at a Type-I error rate of 0.05.

CONCLUSIONS

- The 10% Dumbbell condition appeared to be the most optimal body-weight percentage and load placement for power production.
- The increased PP resulted from a greater force production mainly due to the arms and external load, whilst not drastically decreasing movement velocities.
- Although the 10% Dumbbell condition had decreased segment velocities compared to No Load, the decreases were compensated by the increased velocities of the external load.

PRACTICAL APPLICATION

- Weighted-jumps utilized for muscular power training should include loading variations that maximize power production.
- Although weighted-jumps with a barbell placed on the shoulders are frequently performed for power training, the lack of arm swing may limit its potential to increase power.
- The current findings suggest performing CMVJs with 10% body weight of dumbbells and arm swing may be considered when seeking to maximize power production.

REFERENCES

1. Swinton PA, et al. *Journal of Strength and Conditioning Research*, 26, 2012.
2. Kawamori, N, Haff G. *Journal of Strength and Conditioning Research*, 18, 2004.
3. Wilson GJ, et al. *Medicine and Science in Sport and Exercise*, 93, 1993.
4. Harman EA, et al. *Medicine and Science in Sport and Exercise*, 22, 1990.
5. Hara M, et al. *Human Movement Science*, 27, 2008.