COUNTERMOVEMENT JUMP PERFORMANCE VARIABLES CORRELATE WITH WEIGHTLIFTING PERFORMANCE IN ELITE PARTICIPANTS

Christopher F. Geiser, Nayun Ahn, and Kristof Kipp

Marquette University, Milwaukee, WI, USA

It is valuable to monitor athletes' training efficacy to better guide their conditioning and performance programs. In weightlifting, assessing 1RM routinely may require longer recovery and limit training. The purpose of this study was to identify associations between 1RM weightlifting performance and variables calculated from a maximal countermovement jump (CMJ). Force data were collected and variables calculated for seven elite weightlifters during CMJs. Maximum rate-of-force development (RFD) during the countermovement jump was associated with both Snatch (r^2 0.56, p=0.05) and Clean & Jerk (C&J) (r^2=0.49, p=0.08) performance. Eccentric time (r^2=0.55, p=0.06) and ecc-conc ratio (r^2=0.68, p=0.02) were correlated with C&J performance only. CMJ variables may provide expedient efficient feedback on athlete performance and conditioning in this sport.

KEYWORDS: CMJ, weightlifting, performance.

INTRODUCTION: The sport of weightlifting is one of a few select sports that is judged on a single maximal effort task in competition. There are many options for Strength and Conditioning professionals to choose from when guiding the training of these individuals to improve lifting capacity. However, to judge progress in that effort, those guiding the conditioning of these athletes need feedback on the efficacy of their programming for each athlete to best adjust and modify training in a way that is most beneficial to each individual athlete. In elite lifters, the loads involved in maximal load test or in competition are so great, they prohibit frequent testing. Therefore, surrogate measures of performance are needed to assist in guiding the progress of their training.

It is relatively common in many athletic settings to monitor performance, physical readiness and recovery in athletes by means of serial countermovement jump testing (McMahon et al, 2017). A maximal countermovement jump (CMJ) utilizes a maximal effort without the high loads associated with a 1RM test, and thus can be a valuable assessment of an athlete's status and progress. Multiple variables can be pulled from CMJ data to assess different components of muscular performance (Heishman et al., 2020; Hori et al., 2009). These variables have the sensitivity to reliably identify differences within athletes (Claudino et al., 2017; Kipp et al., 2016). The association between countermovement jump height and weightlifting performance has been well established (Vizcaya et al, 2009, Joffe et al, 2023). Peak power during a CMJ has been correlated to lifting ability (Carlock, et al, 2004, Joffe et al, 2023). However, not many papers have investigated the relationship of CMJ force-time parameters or time-series data to weightlifting performance. In one of the few studies of CMJ components variables, Chavda et all (2023) demonstrated a significant relationship between the propulsive impulse during a CMJ and weightlifting performance of the Snatch and Clean & Jerk lifts, and braking impulse correlated with Clean and Jerk performance. Therefore, the purpose of this investigation was to evaluate a series of variables calculated from a maximal CMJ for correlations with competition performance of the Snatch and Clean & Jerk to answer the question "Do CMJ variables correlate with weightlifting performance in elite level athletes?"

METHODS: After acquisition of informed consent, 7 healthy United States Olympic pool weightlifters (2 male: mass 71.3±5.6kg, 5 female: mass 79.0±30.5kg) performed 3 maximal CMJs each as part of a weekend team training event. Data were collected during a 2-day training weekend and completed testing at the end of their training session on day 1.

Participants were shown a CMJ demonstration and allowed to practice until they were familiarized with the task. Three trials of a maximal CMJ were performed by each athlete, with

a short rest in between trials. Each foot was on a separate Kistler Force Plate (Type 9281EA, Kistler, Winterthur, Switzerland). Subjects stood upright and were instructed to “jump as high and as fast as they could.” Force data were collected at 1000Hz in Vicon Nexus and filtered with 4th order Butterworth filter with a cutoff frequency of 12 Hz in a custom Matlab program. Right and Left leg vertical ground reaction forces were summed, the beginning and take off point were visually identified within the Matlab script, and the dependent variables listed in Table 1 were calculated as described previously (Hori et al, 2009, Kipp et al, 2016) and exported for statistical analysis.
Each subject’s three trial averages were calculated for each variable. Maximum lifting performance for the Snatch and for the Clean & Jerk were recorded from each lifter’s competition nearest the time of CMJ data collection, which ranged from 1 to 3 months prior to data collection. Coefficient of determination (r^2) were calculated and statistically tested using XLSTAT Cloud in Microsoft Excel using $p<0.10$ as a threshold for significance. This threshold was chosen as the chance of Type 2 errors were great due to a small sample size. No statistical correction for multiple comparisons were made to assist in identifying any areas for follow up study, as this investigation was exploratory with a small number of participants.

RESULTS: Seven participants (2 male, 5 female) completed the CMJ trials. Maximum concentric rate of force development was significantly correlated with both Snatch and Clean & Jerk 1RM’s (p=0.05 and 0.08) with r^2 = 0.56 and 0.49 respectively. Eccentric phase time (r^2=0.55) and Eccentric-Concentric time ratio (r^2=0.68) were significantly correlated with the 1RM Clean & Jerk value (p=0.06 and 0.02). No other variables were significantly associated with 1RM weightlifting performance for the Snatch or the Clean & Jerk.

Variable	Minimum	Maximum	Mean	STDev
1RM SN(kg)	84.00	145.00	112.86	19.39
1RM CJ(kg)	110.00	167.00	142.71	22.81
Bodymass(kg)	53.81	135.15	76.83	25.27
Jump Height(m)	0.25	0.54	0.40	0.12
RSI-mod(-)	0.30	0.77	0.50	0.16
Max Vert Force($N\cdot kg^{-1}$)	25.17	31.39	27.89	2.55
Time to Max Force(s)	0.49	0.72	0.62	0.08
MaxConcForce($N\cdot kg^{-1}$)	25.17	31.39	27.85	2.53
MaxEccForce($N\cdot kg^{-1}$)	19.36	28.92	24.54	3.30
MaxNormRFD($N\cdot kg^{-1}\cdot s^{-1}$)	121.83	206.67	162.93	32.44
MaxConcRFD($N\cdot s^{-1}$)	24065.54	50689.43	40038.04	9603.35
MaxEccRFD($N\cdot s^{-1}$)	-4360.00	2827.73	-1457.50	2452.26
Take-off Velocity($m\cdot s^{-1}$)	2.12	3.16	2.67	0.40
Peak Power($W\cdot kg^{-1}$)	38.77	78.60	58.69	12.46
Force at Peak Power(N)	18.66	27.77	23.27	3.48
Vel at peak Power(m/s)	2.00	2.98	2.52	0.37
Positive Work(J)	4.77	9.96	7.47	1.77
Negative Work(J)	-3.05	-0.77	-1.87	0.71
Eccentric Time(s)	0.13	0.24	0.17	0.04
Concentric Time(s)	0.18	0.27	0.23	0.04
Ecc/ConcTime Ratio	0.37	0.46	0.42	0.04

Table 2: Summary values for each variable.

Variables	1RM Snatch r^2	1RM Snatch *p*-value	1RM Clean & Jerk r^2	1RM Clean & Jerk *p*-value
Jump Height	0.15	0.39	0.05	0.63
RSI-mod	0.44	0.11	0.19	0.33
Max Vert Force	0.21	0.30	0.14	0.41
Time to Max Force	0.28	0.22	0.37	0.15
MaxConcForce	0.20	0.31	0.13	0.43
MaxEccForce	0.10	0.50	0.20	0.32
MaxNormRFD	0.00	0.93	0.02	0.79
MaxConcRFD	**0.56**	**0.05**	**0.49**	**0.08**
MaxEccRFD	0.05	0.65	0.00	0.88
Take-off Velocity	0.14	0.41	0.03	0.69
Peak Power	0.30	0.20	0.08	0.54
Force at Peak Power	0.20	0.31	0.04	0.67
Vel at peak Power	0.07	0.56	0.02	0.76
Positive Work	0.05	0.62	0.02	0.74
Negative Work	0.01	0.85	0.02	0.77
Eccentric Time	0.40	0.12	**0.55**	**0.06**
Concentric Time	0.11	0.46	0.05	0.64
Time Ratio	0.33	0.18	**0.68**	**0.02**

Table 3: Coefficients of determination for each variable. Significant differences (*p*<0.05) in bold.

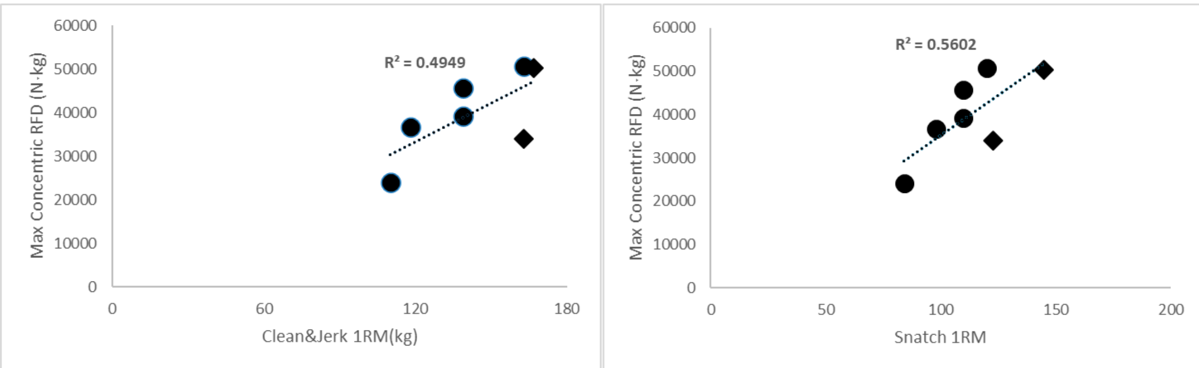

Figure 1: Maximum Concentric Rate of Force Development (RFD) during a Countermovement Jump vs Clean & Jerk and Snatch performance. Circles are female participants, diamonds are male.

DISCUSSION: This study examined a small number of elite weightlifters for correlations between CMJ performance and actual 1RM competition performance in an attempt to identify CMJ variables that may be candidates to best monitor training program effectiveness in a manner that doesn't disrupt training or necessitate a long recovery period. The maximum concentric RFD correlated significantly with 1RM lifting performance for both lifts. This is similar to the findings of Chavda et al (2023) who reported a strong correlation between Propulsive Impulse and these same 1RM lifts. The maximum concentric RFD is in the same phase and is a large determinant of Propulsive Impulse, likely underscoring the correlation of both variables to weightlifting performance in both studies. The strength of the coefficients of determination of 0.56 and 0.49 for these variables are considered very large (Hopkins, 2002). RFD values here were not normalized to bodyweight, which impacts results. We had a range of body sizes and mixed genders, so evaluating the effect of size on RFD values will be considered as more participants are added to these data, and is a limitation of the current investigation. This relationship was not present in the normalized maximum RFD, which also supports that the findings could be related to body weight alone. However the gender and body mass spread across the data were not consistent, which makes this finding more interesting.

Eccentric time and eccentric-to-concentric-time ratio also correlated significantly with 1RM lifting performance for just the Clean and Jerk with an r^2 value of 0.55 and 0.68 respectively. The ability to quickly drop under the weight during a Clean and Jerk is likely a skill that transfers well to the eccentric phase of a countermovement jump to create a greater concentric response, augmenting this correlation. This is also in agreement with Chavda's finding that braking impulse correlates with just Clean and Jerk performance, and not Snatch.

CONCLUSION: A few variables calculated from CMJ performance were associated with weightlifting performance with a strong enough association to be significant in this small sample size of elite weightlifters. While these findings need to be further explored across a greater number of elite lifters, this study provides support for further investigating the association of CMJ performance with weightlifting ability. As our understanding of how CMJ performance relates to weightlifting performance improves, we may find that CMJ performance allows elite lifters to be monitored more regularly without the recovery necessary from max 1RM testing.

REFERENCES

Carlock, Jon M., et al. (2004). The relationship between vertical jump power estimates and weightlifting ability: a field-test approach." *The Journal of Strength & Conditioning Research,* 18(3): 534-539. doi: 10.1519/R-13213.1. PMID: 15320676.

Chavda, S. et al. (2023). Relationship Between Kinetic and Kinematic Measures of the Countermovement Jump and National Weightlifting Performance. *Journal of Science in Sport and Exercise,* https://doi.org/10.1007/s42978-023-00245-w .

Claudino, J. G. et al. (2017). The countermovement jump to monitor neuromuscular status: A meta-analysis. *Journal of Science and Medicine in Sport*, 20(4), 397-402. https://doi.org/10.1016/j.jsams.2016.08.011 .

Heishman, A. D. et al. (2020). Countermovement Jump Reliability Performed With and Without an Arm Swing in NCAA Division 1 Intercollegiate Basketball Players. *Journal of Strength & Conditioning Research*, 34(2), 546-558. DOI: 10.1519/JSC.0000000000002812.

Hopkins W.G. (2002) A scale of magnitudes for effect statistics. *A new view of statistics*, 502.

Hori, N. et al. (2009). Reliability of Performance Measurements Derived From Ground Reaction Force Data During Countermovement Jump and the Influence of Sampling Frequency. *Journal of Strength & Conditioning Research*, 23(3), 874-882. DOI: 10.1519/JSC.0b013e3181a00ca2.

Joffe, Shaun A., et al. (2022). The Relationship of Lower-Body, Multijoint, Isometric and Dynamic Neuromuscular Assessment Variables With Snatch, and Clean and Jerk Performance in Competitive Weightlifters: A Meta-Analysis. *Strength & Conditioning Journal*, 45(4); 411-428. DOI: 10.1519/SSC.0000000000000755.

Kipp, K. et al. (2016). Reactive Strength Index Modified Is a Valid Measure of Explosiveness in Collegiate Female Volleyball Players. *Journal of Strength & Conditioning Research*, 30(5), 1341-1347. DOI: 10.1519/JSC.0000000000001226

McMahon J.J. et al. (2017). Countermovement-Jump-Phase Characteristics of Senior and Academy Rugby League Players. *Int. J. Sport. Physiol. Perform*, 12:803–811. DOI: https://doi.org/10.1123/ijspp.2016-0467

Vizcaya, Francisco J., et al. (2009) Could the deep squat jump predict weightlifting performance?. *The Journal of Strength & Conditioning Research,* 23(3): 729-734. DOI: 10.1519/JSC.0b013e3181a04dc3

ACKNOWLEDGEMENTS: The authors would like to thank USA Weightlifting for their cooperation in helping accomplish this endeavour, and the individual athletes for their time and efforts.