©Journal of Sports Science and Medicine (2014) **13**, 511-515
http://www.jssm.org

Research article

Effect of Load on Peak Power of the Bar, Body and System during the Deadlift

Justin A. Blatnik, Courtney L. Goodman, Christopher R. Capps, Olumide O. Awelewa, Travis N. Triplett, Travis M. Erickson and Jeffery M. McBride ✉
Appalachian State University, Department of Health, Leisure & Exercise Science, Neuromuscular & Biomechanics Laboratory, Boone, NC, USA

Abstract
The purpose of this investigation was to examine how load would affect peak power (PP) of the bar, body and system (bar + body) during the deadlift. Eight healthy males (age = 22.00 ± 2.38 years; height = 1.80 ± 0.05 m; body mass = 88.97 ± 14.88 kg; deadlift one repetition maximum [1RM] = 203.44 ± 21.59 kg, 1RM/BM = 2.32 ± 0.31) with a minimum of 2 years' resistance training experience and a deadlift 1RM over 1.5 times their bodyweight participated in the investigation. During the first session, anthropometric data were recorded and a 1RM deadlift was obtained from the participants. During the second session, participants performed two repetitions at intensities of 30, 40, 50, 60, 70, 80 and 90% of their 1RM in a randomized order. Three-dimensional videography with a force plate was used for data collection and analysis. Peak force (PF), peak velocity (PV), an d PP were calculated for the bar, body, and system (bar + body) during the deadlift. PP occurred at 50%, 30%, and 70% of 1RM for the bar, body, and system, respectively. The optimal loading for the deadlift exercise may vary depending on the desired stimulus and whether the bar, body, or system variables are of most interest.

Key words: Deadlift, peak power, force plate, resistance training.

Introduction

Many investigations have examined the power–load relationships in various resistance training exercises (McBride et al., 2011). The primary motivation for this research arose from evidence that training with loads that maximize peak power (PP) have been shown to increase power production capability (Cormie et al., 2007). Power production has been shown to be a key variable in many sporting events and athletic endeavors (Stone, 1993; Zink et al., 2006). While many investigations have examined the power–load relationship in other exercises, only one investigation has established the power–load curve for the deadlift exercise with PP occurring at 30% of one repetition maximum (1RM) (Swinton et al., 2011). However, they neither separated the bar, body, and system (bar + body) nor used a full range of loading intensities (Swinton et al., 2011). Only a few investigations have separated the body, bar, and system (bar + body) for analysis purposes and none have done so for the deadlift (Hori et al., 2007; McBride et al., 2011; Swinton et al., 2011). Results from McBride et al. (2001) indicate that PP occurred at different loads for the bar, body and system depending on which exercise was examined (McBride et al., 2011). For instance in the squat, PP occurred at 90% of 1RM for the bar, 10% of 1RM for the body, and 50% of 1RM for the system. In contrast, jump squat PP occurred at 80% of 1RM for the bar, 0% of 1RM for the body and 0% of 1RM for the system. During the power clean PP occurred at 90% of 1RM for the bar, 90% of 1RM for the body and 80% of 1RM for the system.

Previous research has reported that training at a load that maximizes PP leads to subsequently greater increases in PP after 12 weeks in comparison to other training loads (isotonic, 30%, 60% and 100% PP) (Kaneko et al., 1983). In a subsequent study the same researchers found that training the elbow flexors with 30% and 100% of maximum isometric force improved power more than training with 30% and 0% of maximum isometric force (Toji et al., 1997). The same researchers again observed that elbow flexor power output had greater increases when trained with multiple power loads compared with one power load and one strength load (Toji and Kaneko, 2004). Cormie et al. (2007) found that strength and power training using the jump-squat for 5 sets x 6 repetitions at body mass in addition to a 3x3 at 90% of 1RM exercise improved power across a broader spectrum of the power–load relationship than power training alone using only 7x6 at body mass. Given its' common usage and the lack of research on the topic, determining the loads that maximize PP in the deadlift may be useful for training athletes in order to improve power production across a spectrum of power–load relationships similar to the stimuli an athlete faces on the field (Cormie et al., 2007).

Thus, the primary purpose of this investigation was to determine a more comprehensive power–load curve for the deadlift exercise and to establish the loads that optimize power for the bar, body, and system (bar + body). Establishing loads that optimize bar power might be useful for throwing athletes or weight lifters who move an external mass; whereas, body or system power might be more relevant to sprint athletes or jump athletes who accelerate their own body mass (McBride et al., 2011).

Methods

Participants

Eight healthy males (age = 22.00 ± 2.38 years; height = 1.80 ± 0.05 m; body mass = 88.97 ± 14.88 kg; deadlift 1RM = 203.44 ± 21.59 kg, 1RM/BM = 2.32 ± 0.31) with a minimum of 2 years' resistance training experience, and a deadlift 1RM over 1.5x their bodyweight were recruited

Received: 12 February 2014 / Accepted: 30 March 2014 / Published (online): 01 September 2014

for the investigation. Participants completed an informed consent sheet and health screening tool to monitor for any contraindications for participation. The project received approval from the Institutional Review Board at Appalachian State University.

Study design

Participants visited the Neuromuscular and Biomechanics Laboratory (NBL) for an orientation and two testing sessions separated by one week. Participants were asked to refrain from performing any type of resistance exercise or strenuous activity 48 hours prior to each testing session. During the first session, anthropometric data (height, weight) was obtained and a 1RM in the deadlift was determined. The warm-up protocol for the 1RM testing involved performing 1 set of 10 repetitions, 1 set of 6 repetitions, and 1 set of 3 repetitions with progressively increasing weight. The participants were then given a maximum of 4 attempts to determine a 1RM (McBride et al., 2011). During the second session, participants performed two repetitions of the deadlift exercise with each load from 30% to 90% of 1RM (in 10% increments). Trials were performed in a randomized fashion utilizing a computer program random number generator. Rest periods of 5 minutes were given between repetitions to minimize the effects of fatigue. All deadlift performances were monitored by a research assistant who had obtained Certified Strength and Conditioning Specialist (CSCS) certification as well as first aid and CPR.

Kinetic and kinematic data collection and analysis

A portable force plate (AMTI, BP6001200, Watertown, MA) was used during all deadlift testing sessions and trials. Kinematic data were collected using a three-dimensional videography system (VICON Systems, Centennial, CO) consisting of seven MX03 + NIR cameras at a frequency of 240 Hz using infrared detection of optical markers. Three optical markers were placed on the bar (left, center, right) and one on the sacrum to denote the body. A global orthogonal coordinate system was used and calibrated using set spaced markers (0.2 m) connected to a rod (VICON Systems, Centennial, CO). A static trial was obtained for each participant to define the anatomical position of the participant and bar position. The mean residual for each camera was 51.1 mm and static reproducibility was 51%. Filtering was performed using a Woltring predicted mean square error quintic spline (VICON Systems, Centennial, CO). Analog signals from the force place were collected for each trial at 1000 Hz using a BNC-2010 interface box with an analog-to-digital card (NI PCI-6014, National Instruments, Austin, TX). LabVIEW (Version 7.1, National Instruments, Austin, TX) was used for recording and analyzing the data. Signals from the force plate underwent rectangular smoothing with a moving average half-width of 12 (Cormie et al., 2007). From laboratory calibrations, force plate voltage outputs were converted into vertical ground reaction force. Kinematic data were analyzed using Vicon Nexus Software (VICON Systems, Centennial, CO). For calculation of bar peak force (PF), peak velocity (PV), and PP, videography displacement–time data from the right-hand side bar optical marker were differentiated into velocity and then acceleration. Acceleration was multiplied by bar mass to determine bar force. Bar power was calculated as force multiplied by velocity. Peak force (PF), peak velocity (PV), and PP of the bar were calculated from the videography displacement–time data. The displacement-time data were single and double differentiated into velocity- and acceleration-time data; the acceleration was than multiplied by bar mass to determine the bar force. This was used in place of a more complex segmental analysis, which requires a full body optical marker set. Previous investigations have shown the validity and reliability of using a single sacral optical marker to track the system center of mass (COM) instead of a full segmental analysis (Gard et al., 2004). System PF, PV, and PP were calculated from the force plate. The system force was determined from the force plate and represented as the theoretical location where all forces are evenly distributed. Force–time data were divided by mass to determine acceleration and then velocity. System power was determined by taking force multiplied by velocity. This value represents mechanical power output (Knudson, 2009). Peak values for the bar, body, and system were obtained from the resulting force–, velocity–, and power–time curves created from the bar optical marker, the sacral optical marker, and the force plate.

Statistical analysis

A general linear model with repeated-measures multivariate analysis of variance was used to examine the performance variables between the bar, body, and system and exercise load (SPSS, Version 11.0). Analyses were followed by least significant difference *post hoc* comparisons. Statistical significance was set at $p \leq 0.05$.

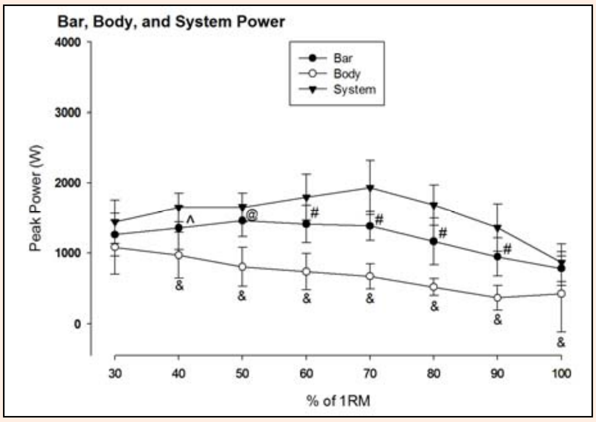

Figure 1. Peak bar, body, and system power in the deadlift from 30 to 100% of deadlift 1RM. # = Bar significantly different from body and system ($p \leq 0.05$). ^ = Bar significantly different from system. @ = Bar significantly different from the body. &= Body significantly different from the system.

Results

Peak power

Bar PP during the deadlift occurred at 50% of 1RM and was significantly different than 30, 80, 90, and 100% of

Table 1. Deadlift bar, body, and system peak power (PP), peak force (PF), and peak velocity (PV) from 30 to 100% of deadlift 1-RM. Data are means (±SD).

	Percentage of deadlift 1RM							
Variable	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Bar PP (W)	1263 (304)*	1358 (310)	1462 (230)	1413 (266)	1385 (208)	1166 (335) *	945 (272) *	778 (240) *
Body PP (W)	1082 (383)	970 (327)	800 (277)*	732 (259)*	667 (179)*	513 (121)*	360 (176)*	419 (539)*
System PP (W)	1443 (309)	1495 (397)	1647 (204)	1795 (324)	1932 (384)	1683 (288)	1361 (338)*	863 (269)*
Bar PF (N)	970 (134)*	1169 (133)*	1354 (159)*	1532 (172)*	1657 (202)*	1816 (210)*	1981 (233)*	2169 (246)
Body PF (N)	1275 (236)	1221 (241)	1174 (237)*	1129 (263)*	1161 (244)*	1062 (196)*	1022 (210)*	1001 (178)*
System PF (N)	2085 (286)*	2139 (314)*	2256 (225)*	2395 (251)*	2483 (298)*	2661 (233)*	2799 (357)*	3005 (401)
Bar PV ($m \cdot s^{-1}$)	1.78 (.19)	1.28 (.18)*	1.24 (.09)*	1.03 (.17)*	.95 (.11)*	.67 (.15)*	.52 (.11)*	.36 (.08)*
Body PV ($m \cdot s^{-1}$)	.91 (.14)	.82 (.17)	.71 (.11)*	.69 (.11)*	.61 (.11)*	.50 (.11)*	.39 (.14)*	.23 (.15)*
System PV ($m \cdot s^{-1}$)	.84 (.14)	.81 (.21)	.82 (.11)	.82 (.20)	.81 (.20)	.66 (.14)*	.50 (.11)*	.29 (.07)*

* Significant difference from highest observed value ($p \leq 0.05$).

1RM (Table 1, Figure 1). The maximum body PP occurred at 30% of 1RM and was significantly different than 50, 60, 70, 80, 90, 100%. System (bar + body) PP occurred at 70% of 1RM and was significantly different than 90 and 100%. An estimated effect size of $\eta^2 = 0.975$, 0.921, and 0.674 at an observed power level of 1.000, 1.000, and 1.000 for bar PF, bar PV, and bar PP respectively. An estimated effect size of $\eta^2 = 0.629$, 0.796, and 0.520 at an observed power level of 0.992, 1.000, and 0.845 for body PF, body PV, and body PP respectively. An estimated effect size of $\eta^2 = 0.925$, 0.684, and 0.530 at an observed power level of 1.000, 0.995, and 0.925 for system PF, system PV, and system PP respectively.

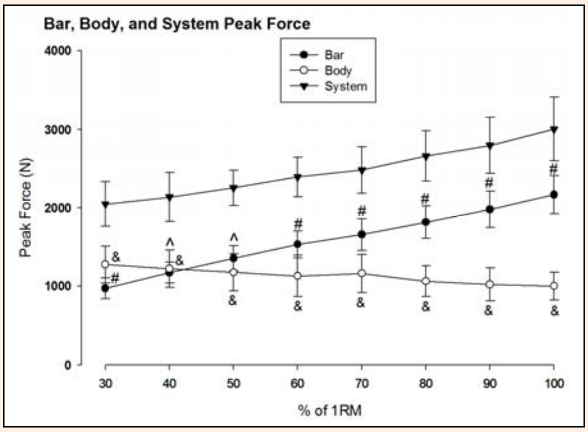

Figure 2. Peak bar, body, and system force (mean + *s*) in the deadlift from 30 to 100% of deadlift 1RM. # = Bar significantly different from body and system ($p \leq 0.05$). ^ = Bar significantly different from system. @ = Bar significantly different from the body. &= Body significantly different from the system.

Peak force

Maximum bar PF during the deadlift occurred at 100% of deadlift 1RM and was significantly different than 30, 40, 50, 60, 70, 80, and 90% (Table 1, Figure 2). Body PF occurred at 30% of 1RM and was significantly different than 50, 60, 70, 80, 90, and 100% (Table 1). System (bar + body) PF occurred at 100% of 1 RM and was significantly different than 30, 40, 50, 60, 70, 80, and 90%.

Peak velocity

Maximum bar PV during the deadlift exercise occurred at 30% of deadlift 1RM and was significantly different than 40, 50, 60, 70, 80, 90, and 100% (Table 1, Figure 3). Maximum body PV occurred at 30% of deadlift 1RM and was significantly different than 50, 60, 70, 80, 90, and 100%. Maximum system (bar + body) PV occurred at 30% of deadlift 1RM and was significantly different than 80, 90, and 100%.

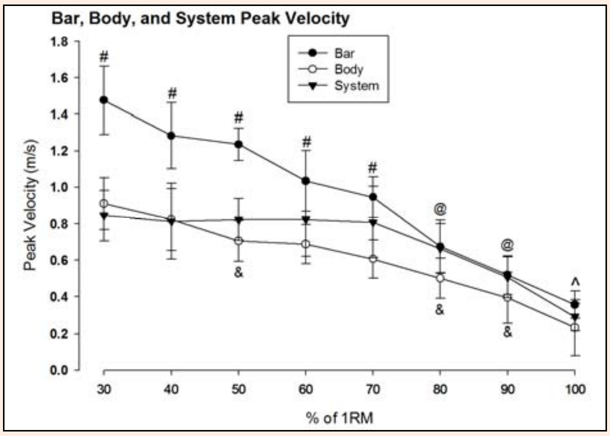

Figure 3. Peak bar, body, and system velocity (mean + *s*) in the deadlift from 30 to 100% of deadlift 1RM. # = Bar significantly different from body and system ($p \leq 0.05$). ^ = Bar significantly different from system. @ = Bar significantly different from the body. &= Body significantly different from the system.

Discussion

This investigation revealed that the PP load differed significantly between the bar, body and system (bar + body). PP occurred at 70% of 1RM for the system, 50% of 1RM for the bar, and 30% of 1RM for the body. The findings were similar to the results from previous investigations using similar methods during the squat, jump squat, and power clean (McBride et al., 2011). Swinton et al. (2011) found that optimal PP was produced at 30% 1RM during the deadlift; however, they also found no significant differences in PP between the 30% and 50% 1RM loads. Also, Swinton et al. (2011) calculated only a single power value from a bar marker and ground reaction force data and did not separate the bar, body, and system.

These loads may have training implications as athletes that accelerate their own body mass would be interested in body or system power and would load the deadlift at times with only 30–70% of 1RM. A throwing athlete or a weightlifter might be more interested in bar power and would thus at times perform the deadlift with a 50% 1RM load. As mentioned previously, training at a load that elicits PP produced the greatest increase in PP after 12 weeks in an elbow flexion model (Kaneko et al., 1983). Weightlifters or throwing athletes who are primarily interested in the power they can impart to an external object (e.g. bar, discus, javelin, etc.) would train at times with loads that elicit peak bar power in order to produce the maximum possible increase in sport-specific performance. Cormie et al. (2007) also demonstrated that a strength load and power load combination during training improved the power–load relationship across a broader spectrum of loading and thus it would be prudent to utilize loads which elicit higher force production at times as well.

Peak force occurred at the highest load tested and the force–velocity relationship predicts that muscle force decreases exponentially with increasing contraction velocity and so maximal force contractions rarely result simultaneously in maximal PP (Hill, 1938). Our data confirmed that the loads which elicited PF also produced the lowest velocities for the bar, body, and system (bar + body). High velocity contractions, similar to high force contractions, tend not to produce PP due to the relatively low force output predicted by the force–velocity relationship (Hill, 1938). Interestingly in our data, PV was observed at 30% of 1RM for the bar, body, and system (bar + body); however, the system velocities did not decline significantly until 70% of 1RM, which is where PP occurred. This may explain the difference between body PP observed at only 30% of 1RM while system PP was observed at 70% of 1RM. Because system velocity was still relatively high unlike body PV at 70%, which had significantly declined to two-thirds of the peak value observed at 30% of 1RM. Bar PV was routinely observed at higher values than body and system PV and this results from the bar having to travel slightly farther than the hips as the bar rests on the shins in the ready position during the deadlift exercise well below the level of the sacrum. The starting positions differ but both the bar and sacrum end at roughly the same vertical height from the floor in the finish position of the deadlift, making the barbell's total travel path slightly longer. The system PV was derived from ground reaction force data whereas body and bar PV values were derived from physical markers and thus system velocities tend to be lower.

Conclusion

In conclusion, the PP output varies dependent upon the load utilized and whether the bar, body, or system is considered. This data can allow athletes to load the deadlift exercise properly dependent upon their desired sport-specificity focus of bar versus body versus system power output. Power outputs observed in this study may lead to future training studies utilizing these loads to elicit PP as well as traditional loads to elicit PF in order to optimize power gains across the entire velocity continuum as had previously been demonstrated (Cormie et al., 2007).

References

Cormie, P., Deane, R. and McBride, J.M. (2007) Methodological concerns for determining power output in the jump squat. *Journal of Strength & Conditioning Research* **21(2),** 424-430.

Cormie, P., McCaulley, G.O. and McBride, J.M. (2007) Power versus strength-power jump squat training: Influence on the load-power relationship. *Medicine & Science in Sports & Exercise* **39(6),** 996-1003.

Gard, S. A., Miff, S.C. and Kuo, A.D. (2004) Comparison of kinematic and kinetic methods for computing the vertical motion of the body center of mass during walking. *Human Movement Science* **22(6),** 597-610.

Hill, A.V. (1938) The heat of shortening and the dynamic constants of muscle. *Proceedings of the Royal Society of London. Series B, Biological Sciences* **126(843),** 136-195.

Hori, N., Newton, R.U., Andrews, W.A., Kawamori, N., McGuigan, M.R. and Nosaka, K. (2007) Comparison of four different methods to measure power output during the hang power clean and the weighted jump squat. *Journal of Strength & Conditioning Research* **21(2),** 314-320.

Kaneko, M., Fuchimoto, T., Toji, H. and Suei, K. (1983) Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. *Scandinavian Journal of Sports Sciences* **5(2),** 50-55.

Knudson, D.V. (2009) Correcting the use of the term "power" in the strength and conditioning literature. *Journal of Strength & Conditioning Research* **23(6),** 1902-1908.

McBride, J.M., Haines, T.L. and Kirby, T.J. (2011) Effect of loading on peak power of the bar, body, and system during power cleans, squats, and jump squats. *Journal of Sports Sciences* **29(11),** 1215-1221.

Stone, M.H. (1993) Literature review: explosive exercises and training. *National Strength & Conditioning Association Journal* **15(3),** 7;9-15.

Swinton, P.A., Stewart, A.D., Keogh, J.W.L., Agouris, L. and Lloyd, R. (2011) Kinematic and kinetic analysis of maximal velocity deadlifts performed with and without the inclusion of chain resistence. *Journal of Strength & Conditioning Research* **25(11),** 3163-3174.

Toji, H. and Kaneko, M. (2004) Effect of multiple-load training on the force-velocity relationship. *Journal of Strength & Conditioning Research* **18(4),** 792-795.

Toji, H., Suei, K. and Kaneko, M. (1997) Effects of combined training loads on relations among force, velocity, and power development. *Canadian Journal of Applied Physiology* **22(4),** 328-336.

Zink, A.J., Perry, A.C., Robertson, B.L., Roach, K.E. and Signorile, J.F. (2006) Peak power, ground reaction forces, and velocity during the squat exercise performed at different loads. *Journal of Strength & Conditioning Research* **20(3),** 658-664.

Key points

- Peak power of the bar, body and system vary depending upon load.
- Loading should be chosen according to desired training effect, with considerations for sport specificity.
- Additional exercises should be investigated concerning the effect of various loads on power.

AUTHORS BIOGRAPHY

Justin A. BLATNIK

Employment

Personal trainer in North Carolina.

Degree

MSc

Research interests

Power training and athletic performance.

E-mail: Blatnikja@gmail.com

Courtney L. GOODMAN

Employment

Graduate assistant in the Neuromuscular Laboratory, Department of Health, Leisure and Exercise Science at Appalachian State University.

Degree

BSc

Research interests

Landing biomechanics and muscle activation in elite jumpers.

E-mail: Goodmancl1@appstate.edu

Christopher R. CAPPS

Employment

Graduate assistant in the Neuromuscular Laboratory, Department of Health, Leisure and Exercise Science at Appalachian State University.

Degree

BSc

Research interests

Strength training for endurance athletes and the stretch-shortening cycle.

E-mail: cappsc@appstate.edu

Olumide O. AWELEWA

Employment

Graduate assistant in the Neuromuscular Laboratory, Department of Health, Leisure and Exercise Science at Appalachian State University.

Degree

BSc

Research interests

The sport of tennis and racket velocity.

E-mail: Plumide@gmail.com

Travis N. TRIPLETT

Employment

Professor in Exercise Science and Chairperson of the Department of Health, Leisure & Exercise Science at Appalachian State University.

Degree

PhD

E-mail: Triplettnt@appstate.edu

Travis M. ERICKSON

Employment

Lecturer at Appalachian State University where he teaches in the department of Health, Leisure, and Exercise Science.

Degree

PhD

Research interests

Examining how resistance training can improve athletic performance.

E-mail: ericksontm@appstate.edu

Jeffery M. McBRIDE

Employment

Professor in Biomechanics at Appalachian State University in the Department of Health, Leisure & Exercise Science and the Director of the Neuromuscular & Biomechanics Laboratory.

Degree

PhD

E-mail: Mcbridejm@appstate.edu

✉ **Jeffrey M. McBride, PhD, Professor**

Director of Neuromuscular & Biomechanics Laboratory, Appalachian State University, Convocation Center Room 045, Boone, NC 28607, USA