

# THE VALIDITY OF VELOCITY MEASUREMENT DURING UPPER-BODY RESISTANCE EXERCISES UNDER VARIABLE LOADS

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The purpose of this study is to compare the velocity of the barbell with the criterion of the velocity of the center of gravity during the explosive bench press lift with different loads. Fifteen highly trained soccer players participated in this study. Three-dimensional upper extremities kinematic data during the bench press were collected. Participants lifted loads of 10, 30, 50, 70 and 90% of one repetition maximum (1RM) with maximal velocity. All upper extremity segments and barbell were modeled as frustra of cones while the barbell was modeled as a cylinder. One way repeated ANOVA revealed that peak barbell velocity was significantly higher with 10, 30 and 50% and the mean barbell velocity was significantly higher with 10 and 30% of 1RM. Additionally, kinematic methods based on the barbell velocity measurement overestimate the velocity of the center of mass.

**KEYWORDS:** bench press, validity, center of gravity, velocity, resistance exercise, load power relationship.

**INTRODUCTION:** In the maximal effort strength training velocities used are one of the most important factors that determine the training stimuli and the consequent training adaptations. In addition, the velocity of the center of gravity influences the power output during the resistance exercise. Conditioners have used devices such as the linear position transducer or FitroDyne Premium (Slovakia) for measuring velocity during the strength training. The velocity of the barbell is supposed to be equal to the velocity of the center of gravity of the system lifted body mass and barbell. Thus, when using these methods for measuring velocity of the center of gravity, we hypothesize that the center of gravity of the system lifted body mass and barbell move in parallel with the barbell. This simplification may overestimate the velocity of the center of gravity and consequently the calculation of the power output. Moreover, the load-velocity and load-power relationship could be influenced as well. The previous study measured the barbell velocity instead of the velocity of the center of mass during the resistance exercise (Hori et al., 2007; Cormie, McBride, & McCaulley, 2007). The purpose of this study is to compare the velocity of the barbell with the criterion - velocity of the center of gravity (COG system upper-extremities and barbell) during the bench press lift with different loads. We hypothesize that the barbell velocity is significantly higher than COG velocity, especially with lighter loads.

**METHOD:** In the current study, fifteen professional male soccer players with a mean  $\pm$  SD age, height, and body mass of  $26.1 \pm 3.9$  years,  $183.3 \pm 6.7$ cm, and  $78.8 \pm 7.2$ kg, respectively, were tested for the maximum upper-body strength (one repetition maximum [1RM], bench press [BP]) and maximal velocity with various barbell loads. Three-dimensional upper extremities kinematic data during the bench press were collected at 247 Hz with a seven camera motion capture system (Qualisys Oqus, Sweden). The linear position transducer device (FitroDyne Premium, Slovakia) presented a sound that the subject could hear throughout the trial and that changed when the downward movement switched to the upward phase of the movement. The testing was performed with the use of free weight form techniques. Each subject visited the laboratory on two separate occasions with one-week rest. In the first session, the subjects were given instructions on the techniques of the bench press (Zatsiorsky, & Kraemer, 2006) and the range of motion for each subject was established without a chest-touch position. The body height, weight of the body and mass of upper extremity segments were then determined with the use of the segmental body composition analyzer (TANITA 418 MA, USA) (Kutač, & Gajda, 2009). The first session

involved one repetition maximum testing according to the protocol published by Kraemer, Ratamess, Fry and French (2006). The second session involved measurement of the velocity while systematically increasing the load 10, 30, 50, 70 and 90% of one repetition maximum. Retro reflective markers were attached to the acromion, greater tubercle of humerus, medial epicondyle of humerus, lateral epicondyle of humerus, styloid process of radius, styloid process of ulna, terminal points of the barbell and the medial point of the barbell. Moreover, four light-weight rigid plates holding triads of markers were attached to the upper arms and forearms. After collecting a static trial in which they were required to stand in the initial upper position with the barbell, three acceptable trials in each load were collected. An acceptable trial was one in which the subject complied with the range of motion during the lift. The subjects were required to lift the load with maximal speed. A three-minute rest was given between each lift. Three trials in each load were collected. The trial with the highest mean velocity was accepted for further analysis. The marker data were processed using Visual 3D software (C-motion, Rockville, MD, USA). All upper extremity segments and barbell were modeled as frustra of cones while the barbell was modeled as a cylinder. The weight of upper extremities was calculated as a product of the mass of upper extremities and gravity acceleration. The velocity of the center of gravity (system upper-extremities and barbell) and the velocity of the barbell were the necessary parameters derived from the visual 3D software. For the statistical analysis, the signal of velocity was normalized to the time of lift. The peak velocity, mean, standard deviation (*SD*) and effect of the size were determined for the velocity for each load. One way repeated ANOVA was used to determine whether any significant differences in the vertical velocity existed between the methodologies. Additional comparisons were made between both techniques under different loading conditions in order to determine their effect on the load-velocity relationship. The reliability of the measurement was estimated by the intraclass correlation coefficient. The statistical significance was accepted at an  $\alpha$  level of  $p \leq 0.05$ .

**RESULTS:** We found out that the mean barbell velocity was significantly higher than the mean COG velocity with 10 and 30% of one repetition maximum loads (Table 1). The peak barbell velocity was significantly higher than COG velocity with 10, 30 and 50% of one repetition maximum loads (Table 2).

**Table 1. Comparison of the mean barbell velocity and COG velocity (system upper-extremities and barbell) for the bench press exercise (n=15)**

Load (% of 1RM)	Velocity of Barbell Mean $\pm$ SD (m/s)		Velocity of COG Mean $\pm$ SD (m/s)		$\Delta v$ (m/s)	ES
10*	1.44	0.12	1.27	0.10	0.17	1.7
30*	1.12	0.09	1.05	0.08	0.07	0.8
50	0.87	0.08	0.86	0.07	0.01	0.1
70	0.63	0.06	0.61	0.06	0.02	0.3
90	0.35	0.06	0.35	0.05	0	0

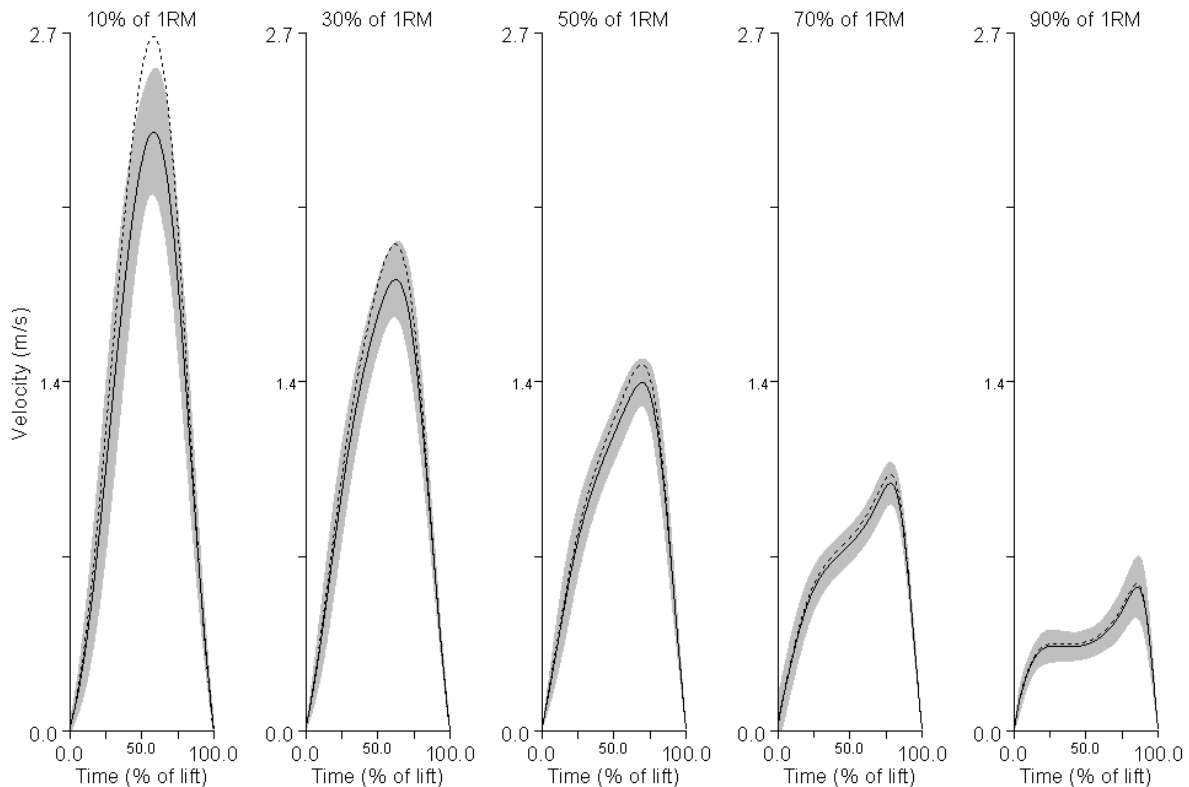
SD = standard deviation,  $\Delta v$ = difference in mean velocity, ES =effect of size

**Table 2. Comparison of the peak barbell velocity and COG velocity (system upper-extremities and barbell) for the bench press exercise (n=15)**

Load (% of 1RM)	Velocity of Barbell Peak $\pm$ SD (m/s)		Velocity of COG Peak $\pm$ SD (m/s)		$\Delta v$ (m/s)	ES
10*	2.78	0.29	2.40	0.25	0.38	1
30*	1.96	0.12	1.81	0.12	0.15	1.25
50*	1.46	0.08	1.40	0.07	0.06	0.9
70	1.01	0.09	0.98	0.09	0.03	0.3
90	0.59	0.12	0.58	0.12	0.01	0.1

SD = standard deviation,  $\Delta v$  = difference in peak velocity, ES = effect of size

Figure 1 shows the effect of the methods and load used on the velocity curve during the normalized time of lift. The instantaneous barbell velocity optically has a similar behavior to COG velocity with all loads. The instantaneous barbell velocity optically shows higher values with all loads than the instantaneous COG velocity does. The curve of the instantaneous COG velocity with higher loads is closer to the curve of the instantaneous barbell velocity.



**Figure 1. Normalized time-velocity relationship for different loads as derived by the two methods examined. The velocity of the barbell is expressed as a dot line and the criterion - velocity of the center of gravity (system upper-extremity and barbell) as a solid line. The gray area represents the between subjects standard deviation of the criterion (COG velocity).**

Both methods displayed intraclass correlation coefficients (ICC) above the minimum acceptable criterion of 0.7 (mean barbell velocity between 0.715 and 0.929, mean COG velocity between 0.708 and 0.927, peak barbell velocity between 0.827 and 0.935 and peak COG velocity between 0.825 and 0.929) and were significant at an alpha level of 0.05 (Baumgartner, & Chung, 2001).

**DISCUSSION:** The purpose of this study was to verify the validity of the barbell velocity measurement during the bench press lift with different loads. We can confirm our hypothesis that the barbell velocity is not a precise estimate of the maximal velocity of the center of gravity during the bench press exercise. The barbell velocity is significantly higher with 10, 30 and 50% of one repetition maximum loads (Table 1 and 2). Based on these findings we could speculate that the load-power and load-velocity relationship is affected by this presumption of a parallel movement of the center of gravity and the barbell during the measurement of the velocity with a device such as FitroDyne Premium or Linear position transducer. Cormie et al. (2007) stated in their research that methods solely reliant on kinematic or kinetic data have limitations when used for the determination of the power output. Cormie et al. recommended a combination of the kinetic and kinematic (barbell velocity) measurement of the power output. This study demonstrated how the kinematic methods based on the barbell velocity measurement overestimate the velocity of the center of mass. These findings evoke a need to verify the effect of overestimating velocity on the load-power and load-velocity relationship.

**CONCLUSION:** The mean barbell velocity was significantly higher than the mean velocity of the center of mass (system barbell and upper extremities) with 10 and 30% (ES 1.7 and 0.8 respectively) of one repetition maximum loads during the explosive bench press exercise. The peak barbell velocity was significantly higher than the peak velocity of the center of mass (system barbell and upper extremities) with 10, 30 and 50% (ES 1, 1.25 and 0.9 respectively) of one repetition maximum loads during the explosive bench press exercise. Subsequent research could show the effect of overestimating velocity on the load-power and load-velocity relationship and consequently the optimal load to achieve the maximal power output during the bench press exercise.

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