

BARBELL TRAJECTORY ANALYSIS OF ELITE US WEIGHTLIFTERS AT THE 2017 PAN-AMERICAN CHAMPIONSHIPS

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INTRODUCTION: Barbell trajectory is one of the greatest indicators of weightlifting (WL) technique. Vorobyev (1978) identified three patterns of barbell trajectory during the WL pull, based generally upon the direction of barbell horizontal displacement at lift-off and points of intersection along a vertical reference line (Figure 1). Several researchers have analyzed competitive weightlifting performances and found that athletes of different levels exhibit different trajectory types as classified by Vorobyev's model (Baumann, Gross, Quade, Galbierz, & Schwartz, 1988; Garhammer, 1985; Hiskia, 1997; Stone, O'Bryant, Williams, Johnson, & Pierce, 1998). Additionally, some parameters of barbell trajectory, such as degree of looping and net horizontal displacement, are potentially associated with the success or failure of an attempt (Stone et al., 1998). Thus, WL coaches may wish to consider the typical barbell trajectories of their athletes to identify possible technical deficiencies to improve WL performance.

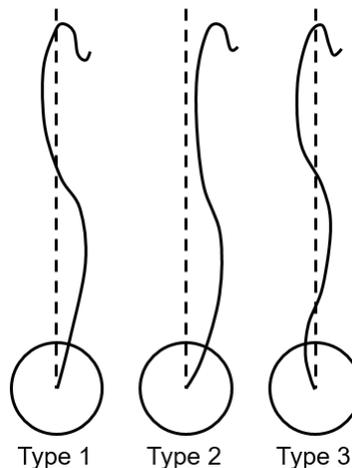


Figure 1. Classification of barbell trajectory types for the snatch lift with the athlete facing to the left. Adapted from Vorobyev (1978).

Few published studies on barbell trajectory have specifically analyzed the performances of US weightlifters. Stone et al. (1998) found differences in barbell path between elite US weightlifters compared to non-US lifters. They speculated these differences as one potential factor contributing to the relatively poor placement of US weightlifters in international competitions (Stone et al., 1998). However, differences in WL technique, as indicated by both lifter and barbell kinematics, have been observed over time (Akkus, 2012; Baumann et al., 1988; Garhammer, 1985; Harbili, 2012; Hiskia, 1997; Stone et al., 1998), so inferences may not be generalizable beyond the athletes and performances characterized within a particular study. Therefore, given the general paucity of published data on US weightlifters, the purpose of this

study was to characterize the barbell trajectories of elite US weightlifters competing in a recent international competition.

METHODS: Each of the heaviest successful snatch attempts ($n = 16$) from Team USA athletes was examined. The team included 17 members, consisting of 8 males (age: $25.4 \text{ y} \pm 5.2$; body mass: $102.06 \pm 24.06 \text{ kg}$) and 9 females. However, one female did not complete any successful attempts and was thus excluded from analysis. Therefore, the descriptive statistics of only 8 female athletes is presented (age: $26.5 \pm 2.6 \text{ y}$; body mass: $71.70 \text{ kg} \pm 32.85$). The study was approved by the institutional review board of East Tennessee State University.

The lifts were recorded using a GoPro HERO4 (San Mateo, CA) at an average sampling frequency of $240 \text{ frames} \cdot \text{s}^{-1}$. The camera was fixed atop a tripod 11 m away from the near-edge of the platform, with the lens facing perpendicular to and in line with the geometric center of the competition platform. The height of the lens was raised 0.71 m above the platform's surface. The vertical diameter of the largest plate (45 cm) nearest to the camera was used to calibrate the distance tool in the Kinovea software (version 0.8.15) for each lift immediately prior to lift-off. Barbell displacement was measured using Kinovea's automatic tracking feature by placing a digitized marker over the center of the near-end of the barbell. Raw displacement data was exported to a spreadsheet and smoothed using a 20-point moving average. Barbell trajectory was plotted from the smoothed displacement data and classified according to the criteria set forth by Vorobyev (1978). A single investigator performed all analysis.

RESULTS: The relative frequency of type 1, 2, and 3 trajectories among all lifters was 25%, 25%, and 50%, respectively (Table 1). This investigation did not attempt to identify any alternative trajectory pattern.

Table 1. Frequencies of trajectory types for the snatch lift by gender and weight class for Team USA athletes at the 2017 Pan-American Weightlifting Championships.

	Type 1	Type 2	Type 3
Female			
48	1	1	–
53	–	1	–
58	–	–	1
63	–	–	1
69	1	–	–
90	1	–	–
90+	–	–	1
Male			
77	1	1	–
94	–	1	1
105	–	–	2
105	–	–	2
Total	4	4	8

DISCUSSION: Lifter and barbell kinematics are interrelated (Akkus, 2012; Baumann et al.,

1988; Chen & Chiu, 2011; Chiu & Liang, 2010; Gourgoulis, Aggeloussis, Garas, & Mavromatis, 2009; Harbili, 2012; Whitehead, Schilling, Stone, Kilgore, & Chiu, 2014). Thus, some trajectory patterns may be characteristic of particular combinations of magnitudes and rates of joint rotations. Barbell trajectory is also indicative of center of mass (COM) displacement of the lifter-barbell system (Garhammer & Taylor, 1984). COM displacement will influence resultant joint torques and can impact the athlete's ability to effectively transmit force to the barbell (Garhammer & Taylor, 1984). Several authors also suggest a potential relationship between certain kinematic parameters and the result of a lift attempt (Baumann et al., 1988; Gourgoulis et al., 2009; Stone et al., 1998). Given these interactions, barbell trajectory may be a useful indicator for coaches regarding an athlete's technical efficiency, which coaches may use to guide instruction and feedback.

Garhammer and Taylor (1984) noted the relationship between horizontal barbell displacement and changes in center of pressure (COP). The athletes in the present study displayed a high frequency of type 3 trajectories in which the barbell initially moves away from the athlete during the first pull. Initial barbell displacement away from the lifter will tend to move the COM and COP anteriorly (Garhammer & Taylor, 1984). Such action increases net joint moments and reduces mechanical efficiency, thereby increasing the muscular effort required to complete the lift (Baumann et al., 1988; Burdett, 1982; Hoover, Carlson, Christensen, & Zebas, 2006).

The predominance of the type 3 trajectory among the athletes in the present study is consistent with previous observations including a variety of athlete pools including elite US and non-US weightlifters (Akkus, 2012; Harbili, 2012; Hiskia, 1997; Hoover et al., 2006). While this trajectory pattern is common, it may negatively influence lifter and barbell movement after lift-off (Stone et al., 1998). Several authors suggest that this pattern may result from a relative lack of strength during initial phases of the pull (Akkus, 2012; Harbili, 2012; Stone et al., 1998). The potential also exists that this pattern is the result of ineffective or incorrect coaching of technique. Nonetheless, effective control of the barbell path can help to reduce the muscular effort required to successfully complete the WL movements (Burdett, 1982; Hoover et al., 2006). Therefore, coaches must consider and address the factors that may influence an athlete's ability to produce an optimal trajectory.

The results of this study indicate that the distribution of trajectory patterns displayed by elite US weightlifters is similar to the relative frequency observed in previous investigations of elite non-US male (Hiskia, 1997) and female (Musser, Garhammer, Rozenek, Crusemeyer, & Vargas, 2014) weightlifters. However, these results cannot be generalized beyond the athletes included in this study. Longitudinal analysis and analysis including a larger sample of elite US and non-US weightlifters, as well as comparisons between successful and unsuccessful attempts, would be beneficial to better understand the potential relationships between barbell trajectory pattern and WL success. Barbell trajectory analysis may be a useful tool for coaches to periodically assess their athletes' technical proficiency.

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