A PROSPECTIVE STUDY OF THE RELIABILITY OF KINOVEA TO ANALYZE LINEAR BARBELL KINEMATICS OF THE WEIGHTLIFTING MOVEMENTS

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INTRODUCTION: The coach's ability to accurately observe and interpret factors of the performance of the weightlifting movements (the snatch, the clean, and the jerk) will impact the quality of the coach's feedback and instruction to the athlete (Rucci & Tomporowski, 2010). However, the speed and complexity of the weightlifting movements can make them difficult to analyze with the naked eye. Motion and video analysis can provide coaches quantitative and qualitative information that enhances or improves coaching feedback (Bruenger, Smith, Sands, & Leigh, 2007; Bruenger et al., 2007; Chiu, Wang, & Cheng, 2010; Garhammer, 1980; Rucci & Tomporowski, 2010; Westenberg, Smith, & Conrad, 2004; Winchester, Erickson, Blaak, & McBride, 2005).

Weightlifting literature has identified barbell trajectory to be an important indicator of weightlifting technique (Akkuş, 2011; Bartonietz, 1996; Baumann, Gross, Quade, Galbierz, & Schwirtz, 1988; Bruenger et al., 2007; Chiu et al., 2010; Garhammer, 1985; Häkkinen, Kauhanen, & Komi, 1984; Reiser II, Smith, & Rattan, 1996; Rossi et al., 2007; Stone et al., 1998; Westenberg et al., 2004; Winchester et al., 2005). Accurate naked-eye evaluation of barbell trajectory can be difficult due to the speed and complexity of the movements, poor viewing angle, interference with line-of-sight, and difficulty remembering bar path based on visual memory (Bruenger et al., 2007; Reiser II et al., 1996; Westenberg et al., 2004).

Simple video analysis allows slow-motion or frame-by-frame playback and can reduce errors due to poor visual memory (Bruenger et al., 2007). It also offers a crude method to analyze barbell trajectory. While informative, such manual techniques are tedious and time-consuming, which may render them impractical. Motion analysis software can largely automate such analysis, increasing the viability of video analysis as a coaching tool by providing instant or near-immediate feedback.

While 3-dimensional (3-D) motion analysis is considered the gold standard, it is impractical in most cases due to associated cost, time, and space constraints. 2-dimensional (2-D) video analysis of single-end, sagittal plane barbell kinematics is suitable for analyzing barbell trajectory during the weightlifting movements that alleviates many of these constraints (Baumann et al., 1988; Chiu et al., 2010; Rossi et al., 2007). However, 2-D software can still be cost-prohibitive.

The purpose of this study is to evaluate the potential of Kinovea, a free 2-D video analysis software, for use as a coaching aid by assessing its reliability in measuring the linear barbell kinematics of the snatch lift.

METHODS: Twenty female collegiate weightlifters were included in this study. Participants provided written informed consent to be filmed during participation in the 2012 USA Weightlifting National University Championships (Championships). The institutional review board of Louisiana State University Shreveport granted approval for this study.

The present study analyzed the medal-earning (1st through 3rd place) snatch lifts for all seven female bodyweight categories at the Championships. Only 20 lifts were analyzed due to one bodyweight category only having two competitors. The subjects' mean body mass was 63.51 (±4.52) kg, and the mean barbell mass lifted was 64.40 (± 12.37) kg.

This investigation divided the snatch lift into six phases to examine five linear barbell kinematic variables that indicate key positions of the barbell's trajectory (Figure 1) (Akkuş, 2011; Baumann et al., 1988; Garhammer, 1985; Gourgoulis, Aggelousis, Mavromatis, & Garas, 2000). The phases of the snatch lift include lift-off, first pull, transition phase, second pull, turnover phase, and catch phase. These phases were determined according to the height of the barbell and the magnitude and direction of knee joint rotation (Akkuş, 2011; Baumann et al., 1988; Garhammer, 1985; Gourgoulis et al., 2000).

A vertical reference line intersecting the center of the barbell at lift-off was used to measure three horizontal variables: maximum horizontal displacement toward the lifter during the first pull; maximum horizontal displacement away from the lifter during the second pull; maximum horizontal displacement toward the lifter after beginning descent from maximum height, and two vertical measurements were made relative to the barbell's position at lift-off: maximum height of barbell; minimum height of barbell during the catch phase (Akkuş, 2011;

Baumann et al., 1988; Gourgoulis et al., 2000).

The investigator recorded all lifts performed on the competition platform during the Championships with a digital video camera (Panasonic PV-GS320, Osaka, Japan) at a sample rate of 30 FPS. The camera lens was set facing the platform centered on the horizontal axis intersecting the center of the platform at a height of 0.76 m above the lifting surface and at a distance of 2.14 m from the edge of the platform. The camera distance from the platform was chosen in order to not interfere with the competition but is a limitation of the study which may affect the accuracy of the results.

A post-hoc video analysis of each lift was performed using Kinovea (version 0.8.15). A single investigator analyzed each lift three times and used the average values from the three analyses as the representative values for each lift during statistical analysis. The data were analyzed to assess intra-rater reliability using Cronbach's α intraclass correlation coefficient ($ICC_{(2,1)}$). The author performed all statistical analysis with SPSS (version 17.0).

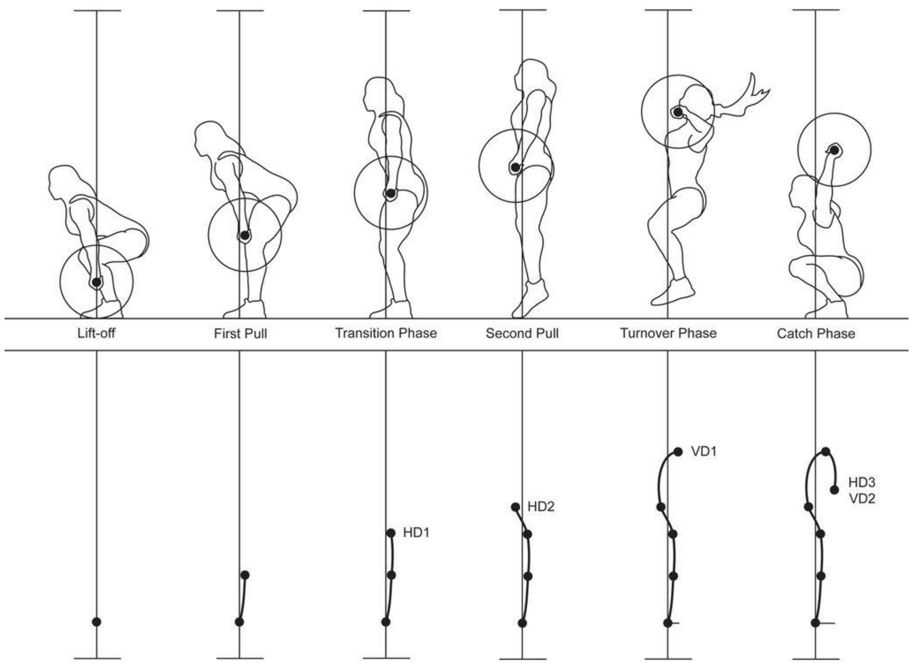

Figure 1. Phases of the snatch lift and measured variables.

RESULTS: A minimum Cronbach's α intraclass correlation coefficient of 0.971, indicating excellent intra-rater reliability ($p < 0.05$). This data along with mean and standard error values for each variable are summarized in Table 1.

Table 1

Linear barbell kinematics and results of reliability test

Variable	M	SE	Cronbach's α
Horizontal kinematics			
Maximum horizontal displacement toward lifter during the first pull (m)	0.066	0.007	0.971
Maximum horizontal displacement away from lifter during the second pull (m)	0.069	0.013	0.989

Maximum horizontal displacement toward lifter after beginning descent from maximum height (m)	0.090	0.011	0.980
Vertical kinematics			
Maximum height of the barbell (m)	1.135	0.024	0.994
Minimum height of the barbell during catch phase (m)	0.939	0.022	0.991

DISCUSSION/PRACTICAL APPLICATION: Kinovea is a free Windows-based 2-D motion analysis software that includes a comparable set of features typical of proprietary or licensed software, including the ability to track and display barbell trajectory and measure linear displacement through simple point-and-click functionality. Barbell trajectory and kinematics may be useful to coaches in the assessment of weightlifting technique and can enhance the coach's feedback and instruction to the athlete during training sessions (Bruenger et al., 2007; Chiu et al., 2010; Garhammer, 1980; Rucci & Tomporowski, 2010; Winchester et al., 2005; Westenberg et al., 2004).

The power of any video analysis software to analyze the weightlifting movements depends largely on its ability to accurately track a fast-moving object. Video sampling rate and camera distance, height, and orientation relative to the subject will also affect this accuracy. Weightlifting movements typically require a video sampling rate of 50 to 100 FPS for accurate full quantitative analysis (Garhammer & Newton, 2013). A minimum distance of 10 m from the subject is necessary to avoid distortion of the distance tools of video analysis software (Garhammer & Newton, 2013), and an appropriate camera viewing angle or multiple camera setup should be selected according to what components of the lifter-barbell system is to be analyzed (Garhammer & Newton, 2013; Gourgoulis et al., 2000).

An initial study by Garhammer and Newton (2013) suggests that Kinovea can yield barbell linear kinematic data similar to Ariel Performance Analysis System (APAS), a "gold standard" 3-D video analysis software, and Dartfish, a 2-D video analysis software popular among coaching professionals. The results of the current study suggest that Kinovea may have potential practical use for coaches to assess weightlifting technique and augment feedback and instruction. Comparative analysis between Kinovea and 2-D video analysis software with established use in the coaching profession, such as Dartfish, may be useful in further determining Kinovea's practical utility for qualitative analysis of barbell trajectory and linear kinematics.

Additionally, investigations to determine if a 30 FPS sampling rate is sufficient to analyze barbell trajectory and linear displacement will be useful for coaches interested in analyzing such measures to guide selection of a video recorder with an adequate sampling rate. Studies comparing video-derived data using Kinovea to measured data from force plate and 3-D video analysis or motion capture are needed to determine Kinovea's quantitative analysis capabilities and to elucidate the full power of Kinovea for coaching professionals.

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