

KINEMATIC CHARACTERISTICS OF THE LEFT HOOK PUNCH IN AN ELITE PROFESSIONAL BOXER: A THREE-DIMENSIONAL MOTION CAPTURE CASE STUDY

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Annotation. This article presents an analysis of segmental joint angle changes and centre of gravity (COG) displacement during a left-hand hook punch performed by an elite professional welterweight boxer, using three-dimensional motion capture (STT Systems 3DMA, 19-marker set, 240 Hz). Two key phases of the punch cycle were compared: the guard phase and the phase of peak trunk-shoulder rotation. The results showed pronounced extension of the left shoulder and elbow ($\Delta = -48^\circ$ and $\Delta = -40^\circ$, respectively), increased rotation of the neck and trunk toward the punching side ($\Delta = -20^\circ$), and a lateral COG shift of 353 mm together with an anterior shift of 109 mm. The findings confirm a proximal-to-distal kinetic chain underlying the left hook punch, initiated at the hip and ankle and completed through shoulder and elbow extension. These data may be useful for technical coaching and future comparative biomechanical research on punch typology among boxers.

Keywords: boxing biomechanics, hook punch, kinematic analysis, kinetic chain, motion capture, elite athlete.

INTRODUCTION

Boxing is a combat sport in which competitive success depends heavily on the ability to deliver forceful, accurately timed strikes while maintaining balance and defensive readiness [9,15]. Punching technique can be broadly divided into linear techniques (jab, straight/cross) and rotational techniques (hook, uppercut), each relying on a distinct sequencing of joint rotations to generate striking force [1,2]. The hook punch is delivered through a horizontal arc, generated primarily by hip and trunk rotation transmitted through the shoulder girdle to a semi-flexed elbow, and is widely regarded by coaches as one of the most mechanically complex and highest-yield scoring techniques at the elite level [3,4]. The theoretical

foundations of striking mechanics, together with the design of instrumented targets suitable for their biomechanical study, have been described in detail elsewhere [16].

Research on boxing performance has traditionally focused on physical and physiological attributes of athletes [9,13], activity profiles and time-motion characteristics of bouts [14], and the technical-tactical factors that differentiate winning from losing performances [10,12]. Physiological response patterns during simulated and competitive bouts have also been reviewed extensively [15], reflecting the broader recognition that competitive outcomes in boxing are determined by a combination of conditioning, tactics, and technique.

A separate body of work has examined punch force and impact characteristics using dynamometry and instrumented targets [7], the mechanical and anthropometric contributors to punching force in combat-sport athletes more broadly [8], and the biomechanics of head loading resulting from boxing punches, which underscores the practical importance of understanding punch mechanics for injury prevention and protective equipment design [6]. More recent work has applied wearable inertial sensors to quantify hand speed during punching [11], while other studies have analysed the general kinematic and tactical characteristics of competitive bouts [12].

Despite this growing body of literature, three-dimensional kinematic descriptions of the hook punch specifically — as opposed to force output, activity profiles, or the straight punch — remain comparatively scarce, particularly in elite professional boxers competing at world level [1,4]. Understanding the segmental contributions and temporal sequencing of the lower limb, trunk, and upper limb during the hook is important both for technical coaching and for injury-risk management, given the torsional loading placed on the lumbar spine and knee during rapid trunk rotation [3,5].

The purpose of this case study was to describe the joint kinematics and centre of gravity displacement associated with a left-hand hook punch performed by an elite professional welterweight boxer, using three-dimensional motion capture, in order to characterise the kinetic chain underlying this technique. This work extends

the authors' prior kinematic research on the jab [17] and the uppercut [18,19] to the hook, the remaining major punch type in the boxer's technical repertoire.

MATERIALS AND METHODS.

Full-body kinematic data were captured using a three-dimensional motion analysis system (STT Systems 3DMA) with a 19-marker full-body set, sampled at 240 Hz. The system provided real-time computation of segmental joint angles (flexion/extension, abduction/adduction, and rotation, as applicable) for the neck, trunk, shoulders, elbows, hips, knees, and ankles, together with three-dimensional centre of gravity (COG) coordinates.

Following a standardised warm-up, the participant performed a series of technical combinations within the capture volume [context to be confirmed]. A left-hand hook punch sequence was selected for detailed analysis. Two discrete time points within the punch cycle were extracted: (i) the guard phase, corresponding to the upright stance immediately preceding punch initiation (frame 1409, $t = 5.208$ s), and (ii) the peak rotation phase, corresponding to maximal trunk-shoulder rotation during punch delivery (frame 1575, $t = 6.134$ s), identified from the shoulders-hips rotation trace in the trunk angle time series.

Segmental joint angles and COG coordinates were extracted at each of the two phases directly from the motion capture system's metrics dashboard. Angular differences (Δ) between the guard and peak rotation phases were calculated for each joint to characterise the direction and magnitude of segmental motion contributing to punch execution. Descriptive comparison was used given the single-participant, single-trial case-study design.

RESULTS

Table 1 presents the segmental joint angles recorded during the guard phase and the peak rotation phase of the left hook punch, together with the angular change (Δ) between phases. Table 2 presents the corresponding three-dimensional COG displacement, and Figure 1 illustrates the key angular changes.

The transition from the guard phase to peak rotation phase was characterised by the largest angular changes at the left shoulder (flexion/extension $\Delta = -48^\circ$) and left elbow ($\Delta = -40^\circ$), reflecting extension and opening of the punching arm through the

horizontal arc characteristic of the hook. Neck and trunk rotation increased toward the punching side (neck rotation $\Delta = -20^\circ$), while trunk anterior/posterior tilt decreased ($\Delta = -7^\circ$), indicating a more upright trunk position at peak rotation relative to the guard. The right ('guard') shoulder showed increased flexion ($\Delta = +27^\circ$), consistent with its stabilising role during the punch.

Lower-limb changes showed an increase in left ankle dorsiflexion ($\Delta = +10^\circ$) and a shift toward plantar flexion at the right ankle ($\Delta = -14^\circ$), together with increased left hip abduction ($\Delta = +9^\circ$) and left hip extension ($\Delta = -19^\circ$), consistent with a rear-leg pivot and drive pattern. The COG shifted 353 mm mediolaterally and 109 mm anteriorly between phases, with a negligible vertical change (+9 mm), indicating that the hook punch was generated predominantly through horizontal rotational displacement of the COG rather than vertical drive.

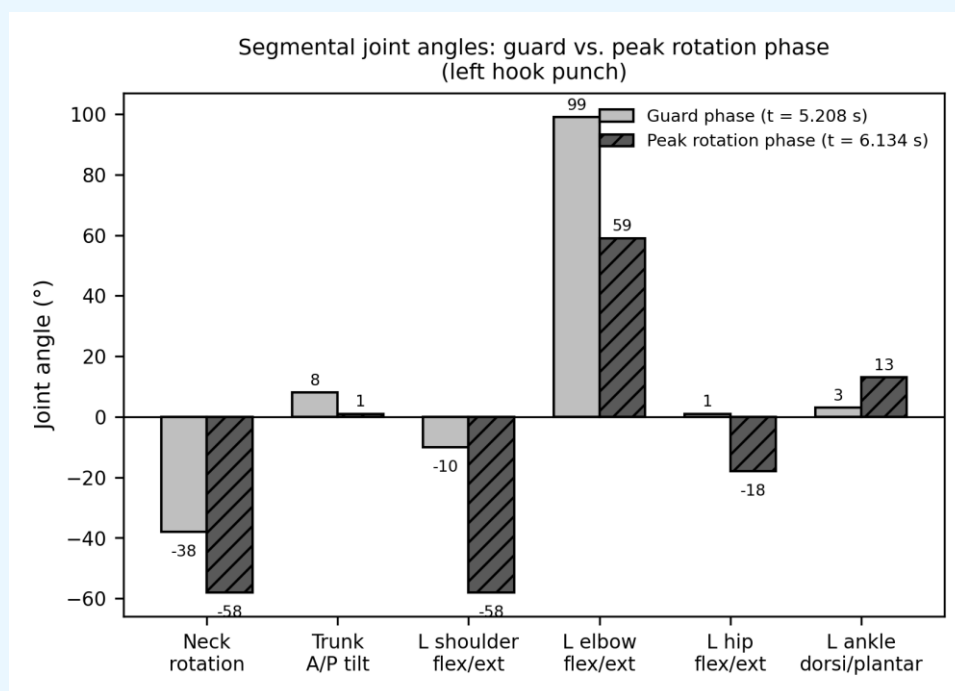


Figure 1. Comparison of key segmental joint angles between the guard phase (t=5.208 s) and the peak trunk-shoulder rotation phase (t=6.134 s) of the left hook punch.

Table 1

Segmental joint angles during the guard and peak rotation phases of the left hook punch

Joint / Segment Angle	Guard Phase	Peak	Δ ($^\circ$)	Direction of
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	(t=5.208s)	Rotation (t=6.134s)		Change
Neck flexion/extension (°)	19	28	+9	↑ flexion
Neck lateral flexion (°)	-4	-12	-8	↑ left lateral flexion
Neck rotation (°)	-38	-58	-20	↑ left rotation
Trunk anterior/posterior tilt (°)	8	1	-7	↓ forward lean (more upright)
Trunk lateral flexion (°)	-4	-4	0	unchanged
Left shoulder flexion/extension (°)	-10	-58	-48	large ↑ extension
Right shoulder flexion/extension (°)	17	44	+27	↑ flexion (guard arm)
Left shoulder abduction/adduction (°)	64	42	-22	↓ abduction
Right shoulder abduction/adduction (°)	75	37	-38	↓ abduction
Left elbow flexion/extension (°)	99	59	-40	↑ extension
Right elbow flexion/extension (°)	97	104	+7	slight ↑ flexion
Left hip flexion/extension (°)	1	-18	-19	↑ extension
Right hip flexion/extension (°)	5	11	+6	↑ flexion
Left hip abduction/adduction (°)	16	25	+9	↑ abduction

Right hip abduction/adduction (°)	16	18	+2	slight ↑ abduction
Left knee flexion/extension (°)	7	19	+12	↑ flexion
Right knee flexion/extension (°)	30	18	-12	↑ extension
Left ankle dorsi/plantar flexion (°)	3	13	+10	↑ dorsiflexion
Right ankle dorsi/plantar flexion (°)	12	-2	-14	↑ plantar flexion

Table 2

Centre of gravity (COG) position during the guard and peak rotation phases

Centre of Gravity	Guard Phase	Peak Rotation	Δ
COG X (mediolateral, mm)	726	373	-353
COG Y (vertical, mm)	929	938	+9
COG Z (anteroposterior, mm)	-534	-425	+109

DISCUSSION. The present case study describes the segmental kinematics of a left hook punch performed by an elite professional boxer, revealing a pattern consistent with proximal-to-distal kinetic chain sequencing previously described for rotational striking techniques [1,2]. The substantial increase in left shoulder and elbow extension, combined with increased hip abduction/extension and ankle-driven pivoting of the rear leg, supports the view that hook punch force is generated through coordinated rotation of the lower limb, pelvis, and trunk, transmitted sequentially to the shoulder girdle and arm [3,8].

The relatively small vertical COG displacement (+9 mm) alongside a larger horizontal (mediolateral and anteroposterior) displacement is consistent with the

hook's characterisation as a predominantly rotational rather than linear-drive technique, distinguishing it mechanically from the straight punch, where greater anteroposterior and vertical COG contribution has typically been reported [1,4].

The decrease in trunk anterior/posterior tilt at peak rotation, together with increased neck rotation toward the punching side, may reflect a technical strategy of maintaining a more upright, rotationally stable trunk position to preserve balance and visual tracking of the opponent while generating power through hip-trunk rotation rather than forward lean, consistent with tactical analyses emphasising balance retention during scoring actions [10,12].

As a single-participant, single-trial case study, these findings should be interpreted as descriptive and hypothesis-generating rather than generalisable. Future work should extend this analysis across multiple trials and boxers of varying weight classes and skill levels [9,13], and should incorporate kinetic (force and impulse) data alongside the kinematic description presented here [4,5,7]. Following the qualification-related and training-intervention approaches already applied by the authors to the uppercut [18,19], future studies could similarly examine how hook punch kinematics differ by boxer qualification level and respond to targeted biomechanics-based training.

CONCLUSION. This case study provides a three-dimensional kinematic description of the left hook punch in an elite professional boxer, identifying a proximal-to-distal kinetic chain originating at the rear ankle and hip, transmitted through trunk and neck rotation, and completed through shoulder and elbow extension of the punching arm. These findings contribute descriptive normative data on hook punch technique at the elite level and may inform coaching cues and future comparative biomechanical research across punch types and athlete populations.

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