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PHASE-SPECIFIC JOINT ANGLE VALUES DURING A LEFT-HAND STRAIGHT PUNCH TO THE BODY IN STUDENT BOXERS

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ABOUT ARTICLE

Key words: boxers, left hand, straight punch to the body, phase-specific joint angles, joint dynamics, hip and knee flexion/extension, punching technique, sports pedagogy.

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Abstract: This study investigated the phase-specific joint angle dynamics during the execution of a left-hand straight punch to the body in student boxers. Measurements were conducted across the main movement phases—contact, lift-off, knee lift, mid-swing, and mid-support. For each phase, hip, knee, and ankle flexion/extension angles were determined relative to the vertical axis, and their phase-dependent variability was assessed. The results demonstrated that during the execution of a left-hand straight punch, dynamic flexion/extension angles of the hip and knee joints reach their maximum values in the mid-swing phase, contributing to increased punch force and velocity. Differences between the right and left joints were also observed, indicating asymmetric but functionally coordinated movement patterns. Joint angles referenced to the vertical axis played a significant role in ensuring movement stability and punching effectiveness. The findings provide a scientific basis for the development of training recommendations aimed at optimizing punching technique and improving strike mechanics in pedagogical and sports training processes for boxers.

Introduction. In boxing, particularly in the study of left-hand straight punches to the body in student boxers, phase-specific joint angles and kinematic parameters play a crucial role. Research indicates that punching effectiveness depends not only on muscular strength but also on joint coordination, muscle activation, and the sequential organization of body movements across phases [1,2,11].

The analysis of punching technique and phase-specific joint angles allows for the assessment of muscle coordination and movement efficiency. Studies by Pavlenko et al. [3], Medvedeva et al. [8], and Shevchuk et al. [5] have examined straight punch techniques and joint phase characteristics in boxers. In addition, Stanley [6] and Loturco et al. [18] investigated maximal punching force and movement efficiency in professional and youth boxers, aiming to identify the influence of kinematic variables on punch force.

When studying punching techniques in young athletes, the analysis of distinct movement phases—contact, toe-off, mid-swing, and mid-support—is of particular importance [17,12,13]. Such analyses contribute to the individualization of training programs, reduction of injury risk, and enhancement of punching effectiveness. Furthermore, studies focusing on lower-limb kinetics and muscular strength [26,27,25] demonstrate a strong relationship between movement stability, lower-limb and hip strength, and punching performance.

Research in kinematics and kinetics provides valuable insights for optimizing pedagogical training methods and improving technical proficiency in young boxers [14,15,16,20]. Phase-specific joint angles and kinematic parameters are therefore essential for enhancing the effectiveness of left-hand straight punches to the body, developing muscle coordination, and scientifically optimizing training processes in student boxers.

The literature review indicates that the investigation of biomechanical and kinematic parameters of punching, assessment of muscle coordination, and evaluation of phase-specific body positions represent key scientific foundations for the development of effective pedagogical training programs for student boxers. However, most existing studies have focused on elite or professional athletes, while systematic biomechanical research on student-level boxers remains limited, highlighting the need for further investigation in this population.

The aim of this article is to analyze phase-specific lower-limb joint angle characteristics during the execution of a left-hand straight punch to the body in student boxers, with the aim of identifying key biomechanical patterns that contribute to punching effectiveness and movement stability.

Research Tasks:

- To determine phase-specific joint angles of the hip, knee, and ankle joints during the execution of a left-hand straight punch to the body in student boxers.

- To analyze changes in flexion/extension angles of the right and left lower-limb joints across the contact, toe-off, mid-swing, and mid-support phases.

- To evaluate hip flexion/extension angles relative to the vertical axis in order to assess body inclination and postural alignment during punch execution.

- To assess the variability of joint angle parameters using coefficients of variation to determine movement consistency among student boxers.

- To identify the biomechanical role of lower-limb coordination in the formation of effective punching mechanics.

- To provide a scientific basis for optimizing pedagogical training methods aimed at improving punching technique and reducing injury risk in student boxers.

Materials and Methods.

Participants

Eighteen male student boxers (n = 18) with regular training experience voluntarily participated in the study. All participants were free from musculoskeletal injuries at the time of testing and provided informed consent prior to data collection. The study procedures conformed to ethical standards for research involving human participants.

Experimental Design

A cross-sectional biomechanical study design was employed to examine phase-specific joint angle characteristics during the execution of a left-hand straight punch to the body. Each participant performed standardized punch trials under controlled laboratory conditions.

Data Collection Procedure

Kinematic data were collected using a three-dimensional motion analysis approach. Reflective markers were placed on anatomical landmarks of the lower limbs in accordance with standard biomechanical modeling protocols. Participants executed left-hand straight punches to a fixed target following a standardized warm-up. Multiple trials were recorded, and the most technically consistent trials were selected for analysis.

Movement Phase Definition

Punch execution was divided into four key movement phases based on kinematic events:

Contact phase – moment of punch impact with the target;

Toe-off phase – initiation of foot propulsion;

Mid-swing phase – peak forward movement of the swinging limb;

Mid-support phase – post-impact stabilization with body weight supported on the lead leg.

Kinematic Analysis

Joint angles of the hip, knee, and ankle joints of both lower limbs were calculated in the sagittal plane. Flexion/extension angles were analyzed both in absolute terms and relative to the vertical axis to assess body alignment and forward inclination during punch execution.

Statistical Analysis

Descriptive statistics were used to summarize the data, including mean values (Mean ± SD) and coefficients of variation (V%) to evaluate inter-individual variability and movement consistency. All analyses were conducted using standard statistical software, and results were interpreted at a descriptive level appropriate for biomechanical performance analysis.

Result and Discussion. The phase-specific behavior of the right hip flexion/extension angle demonstrates a clear and structured contribution of the lower limb to punch execution. During the contact phase, the right hip was positioned in slight extension (−3.96°), indicating a stabilized and lowered body posture at the moment of impact. This position supports balance maintenance and efficient force transmission through the kinetic chain. The coefficient of variation (12.6%) suggests relatively low inter-individual variability and consistent technique among participants (Table-1).

Table-1

Phase-specific joint angle values during a straight punch to the body with the left hand in student boxers (n = 18)

T/r	Parameter	Contact Mean ± SD	V%	Toe off Mean ± SD	V%	Mid-swing Mean ± SD	V%	Mid-support Mean ± SD	V%
1.	Right hip flexion/extension (°)	-3.96±0.50	12.6	-0.05±0.01	12	20.25±2.40	11.9	8.46±1.05	12.4
2.	Left hip flexion/extension (°)	18.19±2.10	11.5	17.14±2.00	11.7	17.80±2.05	11.5	35.61±4.20	11.8
3.	Right hip flexion/extension relative to the vertical (°)	-1.38±0.16	11.6	2.50±0.31	12.3	20.14±2.50	12.4	10.22±1.25	12.2
4.	Left hip flexion/extensi	17.80±2.00	11.2	17.82±2.20	12.3	17.86±2.25	12.6	32.45±4.10	12.6

	on relative to the vertical (°)								
5.	Right knee flexion/extension (°)	7.76±0.90	11.6	16.39±2.00	12.2	34.07±4.20	12.3	28.21±3.50	12.4
6.	Left knee flexion/extension (°)	38.85±4.80	12.4	36.71±4.80	13.1	32.04±3.90	12.2	61.95±7.80	12.6
7.	Right ankle flexion/extension (°)	9.27±1.10	11.9	18.05±2.10	11.6	19.55±2.40	12.3	19.48±2.50	12.8
8.	Left ankle flexion/extension (°)	14.61±1.90	12.2	9.61±1.10	11.5	-1.13±0.12	10.6	19.20±2.40	12.5

In the toe-off phase, the right hip angle approached a neutral position (−0.05°), reflecting the transition from stabilization to propulsion. This near-neutral alignment indicates coordinated timing between hip motion and lower-limb push-off, facilitating the transfer of ground reaction forces toward the trunk.

The mid-swing phase was characterized by a marked increase in right hip flexion (20.25°), representing the peak dynamic involvement of the swinging limb. This phase corresponds to maximal lower-limb contribution to forward body motion and trunk rotation, which are essential for enhancing punching velocity.

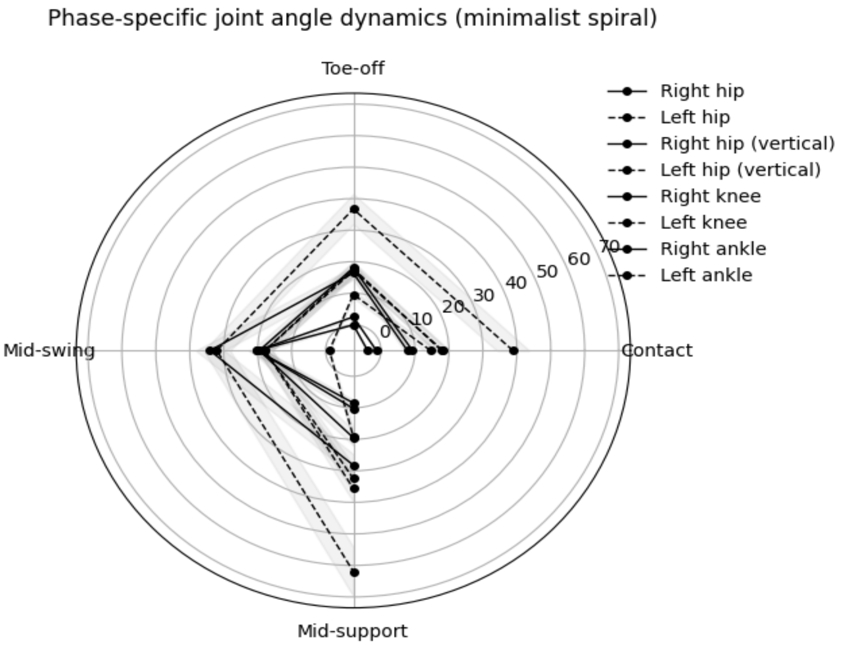

Figure 1. Minimalist spiral representation of phase-specific lower-limb joint angle dynamics during a left-hand straight punch to the body in student boxers (n = 18). Solid

lines represent right-side joints, whereas dashed lines represent left-side joints. Radial distance indicates mean joint angle values (°), and shaded areas represent ± SD.

During the mid-support phase, the right hip flexion decreased to 8.46°, indicating a shift toward post-impact stabilization and controlled deceleration. This adjustment contributes to balance restoration following punch execution. Across all phases, variability remained within a narrow range (11.9–12.6%), confirming a stable and reproducible movement pattern.

The left hip flexion/extension angle remained consistently flexed across all movement phases, indicating its dominant role as the lead and supporting limb during punch execution. During the contact phase, the left hip demonstrated a flexed position (18.19°), reflecting a stable postural alignment at impact. A similar magnitude of flexion was maintained during the toe-off (17.14°) and mid-swing (17.80°) phases, suggesting limited angular fluctuation and sustained support function throughout the dynamic portion of the movement.

In contrast, a pronounced increase in left hip flexion was observed during the mid-support phase (35.61°), indicating a shift of body weight onto the lead leg and enhanced post-impact stabilization. The coefficient of variation remained low and stable across phases (11.5–11.8%), demonstrating minimal inter-individual variability and a consistent technical pattern among participants.

For the right hip, the angle relative to the vertical was slightly negative during the contact phase (−1.38°), indicating a near-upright trunk–pelvis alignment at impact. During the toe-off phase, the angle shifted to a small positive value (2.50°), reflecting the initiation of forward body inclination associated with propulsion. The mid-swing phase showed a marked increase in right hip flexion relative to the vertical (20.14°), representing the peak forward inclination of the lower limb and trunk system. In the mid-support phase, this angle decreased to 10.22°, indicating partial realignment toward a more upright posture during post-impact stabilization. Variability across phases remained low (V% = 11.6–12.4).

For the left hip, flexion relative to the vertical remained consistently positive during the contact, toe-off, and mid-swing phases (≈17.8°), indicating a stable forward-inclined alignment of the lead side throughout the dynamic portion of the movement. A substantial increase was observed during the mid-support phase (32.45°), reflecting a pronounced forward inclination associated with weight transfer onto the lead leg and post-impact control. The coefficient of variation ranged from 11.2% to 12.6%, suggesting a homogeneous movement pattern among participants.

Conclusion. This study examined the technique of a left-hand straight punch to the body in student boxers using a phase-specific kinematic analysis of lower-limb joint angles. The findings demonstrate that punch execution is characterized by a coordinated, phase-dependent interaction of the hip, knee, and ankle joints, confirming the essential role of the lower extremities in effective punching mechanics.

The results indicate that the right hip joint plays a key role in initiating and regulating movement through a stabilization–propulsion–dynamic swing–re-stabilization sequence, functioning as an important element of the kinetic chain. In contrast, the left hip joint maintains a more stable flexed position throughout most phases, with a marked increase in flexion during the mid-support phase, highlighting its primary function in weight bearing and post-impact stabilization.

Analysis of hip angles relative to the vertical revealed that controlled forward body inclination varies across movement phases and contributes to punch effectiveness by optimizing force transfer and balance. The observed changes in knee and ankle joint angles further support their involvement in propulsion, shock absorption, and postural control, facilitating efficient transmission of ground reaction forces to the upper body.

The relatively low coefficients of variation (approximately 10–13%) across all joints and phases indicate a stable and reproducible movement pattern among student boxers, suggesting the presence of a consistent biomechanical technique developed through training.

Overall, the findings confirm that the effectiveness of a left-hand straight punch to the body depends not solely on upper-body strength, but on the coordinated phase-specific mechanics of the lower limbs and body alignment. These results provide a scientific basis for optimizing pedagogical training programs for student boxers, with an emphasis on improving lower-limb coordination, postural stability, and phase-specific movement control to enhance punching performance and reduce injury risk.

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