

WHOLE-BODY KINEMATICS OF THE FAST MOMTONG JIREUGI (MIDDLE-SECTION PUNCH) IN TAEKWONDO: A SINGLE-CASE 3D MOTION-CAPTURE STUDY

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Abstract

The middle-section punch (Momtong Jireugi) is a fundamental technique of taekwondo training and poomsae, yet its whole-body kinematics have not been described. This single-case study aimed to describe the timing and joint kinematics of the punching arm, the pull-back arm, the lower limbs, and the trunk during a fast Momtong Jireugi. A 19-year-old male taekwondo athlete performed right-hand punches at maximal speed while full-body kinematics were recorded with an optical motion-capture system (STT 3DMA, 19-marker model, 120 Hz). Two consecutive punches were analyzed after digitizing the joint-angle curves from the software report (mean absolute difference from reported extrema 0.75°) and aligning them to full elbow extension. Both punches followed the same sequence. The rear hip began to extend about 0.35–0.38 s before the strike and was largely extended ($36\text{--}37^\circ$ range) before the elbow finished. The opposite arm completed its pull-back (to 133° elbow flexion) 0.18 s before the strike, exactly when the punching elbow began to extend. The punching shoulder rose to $52\text{--}53^\circ$ of flexion and adducted from $65\text{--}72^\circ$ to $14\text{--}20^\circ$ of abduction, and the elbow extended last, by $117\text{--}121^\circ$ in 0.24 s (about $490\text{--}500^\circ/\text{s}$), to $26\text{--}28^\circ$. The trunk remained nearly upright ($4\text{--}7^\circ$ anterior tilt). The punch thus showed a leg-first, pull-back-then-punch, elbow-last organization. Six teaching checkpoints are proposed. Because the data come from one athlete and two punches, the findings are exploratory.

Keywords: taekwondo; Momtong Jireugi; punch; kinematics; motion capture; technique teaching; single-case study

Introduction

Straight punches in combat sports are produced by a chain of segment actions that begins in the legs and ends with extension of the elbow (Putnam, 1993). In karate, skilled athletes show a proximal-to-distal pattern of joint motion and muscle activation during the reverse punch (Vences Brito et al., 2011). In boxing, the straight punch involves coordinated motion of the lower limbs, trunk, and arm (Cheraghi et al., 2014), whole-body punch kinematics differ between junior and elite boxers (Dinu & Louis, 2020), and punching force depends on the contribution of the lower body and trunk as well as the arm (Lenetsky et al., 2013).

In taekwondo, the middle-section punch (Momtong Jireugi) is one of the first techniques taught and a core element of poomsae. It is traditionally performed with a simultaneous pull-back of the opposite arm to the hip, and coaches emphasize a stable, upright trunk and a drive from the rear leg. Although these principles are widely taught, no study was found that measured the whole-body kinematics of the Momtong Jireugi, or the timing between the punching arm, the pull-back arm, and the legs. Objective data of this kind could turn qualitative coaching cues into measurable checkpoints.

The aims of this single-case study were therefore (a) to describe the kinematics of the punching arm, the pull-back arm, the lower limbs, and the trunk during a fast Momtong Jireugi, (b) to establish the timing of key events relative to the strike, and (c) to derive observable checkpoints for teaching the technique.

Materials and Methods

Design and Participant

A single-case descriptive design was used, which is appropriate when the aim is to document an individual movement solution in detail (Bates, 1996). The participant was a 19-year-old male taekwondo athlete who punched with the right hand from a stance with the left leg forward. He was free of injury at the time of testing.

Instrumentation and Procedure

Testing took place on 27 October 2025 in the Hi-Tech Sports Laboratory of the Uzbek State University of Physical Education and Sport. Kinematics were recorded with an optical motion-capture system (OptiTrack cameras, Motive) and processed in STT 3DMA 2023.0 (STT Systems, San Sebastián, Spain) using the 19-marker full-body model at 120 Hz. After a standardized warm-up, the participant performed Momtong Jireugi at maximal speed. The recording lasted 140 s; the analysis window (91.5–100.0 s) contained two consecutive complete right-hand punches, both of which were analyzed. A screen recording of the 3D reconstruction was used to confirm the punching arm and stance.

Data Processing

The 3DMA full-body report provided the minimum, maximum, and range of each joint angle together with angle–time plots for the trunk, neck, shoulders, elbows, hips, knees, and ankles. Because the time-series files were not exported, the curves were digitized with a custom Python script (OpenCV, NumPy) that detected the plot frame, read the axis scales, and traced each curve by color. Digitization accuracy was checked against the 38 extrema reported by the software (mean absolute difference 0.75° , median 0.61°). Curves were resampled to 120 Hz and smoothed with a Savitzky–Golay filter (13 points, third order).

Three problems in the report were identified and handled. First, the plot labeled right ankle in the lower-limb section was an exact copy of the right knee plot; the right ankle curve was therefore taken from the full-body section. Second, the software's gait-analysis table listed a maximum right elbow angular speed of $165^\circ/\text{s}$, far below the mean elbow extension velocity visible in its own angle curve (about $490\text{--}500^\circ/\text{s}$); because that table is computed by a module designed for running and walking, its values were not used. Third, neck rotation showed a range of about 145° within each punch, which exceeds what is expected for a punch and probably reflects the model's head–trunk reference during rapid trunk rotation or marker occlusion; neck rotation was therefore not interpreted.

Events and Variables

Full elbow extension of the punching arm (minimum elbow flexion) was taken as the strike instant ($t = 0$). The following events were identified: peak rear-hip flexion (start of the leg drive), 90% completion of rear-hip extension, peak elbow flexion before the punch (cocking), 10% onset of elbow extension, 90% completion of the pull-back of the opposite elbow, and peak shoulder flexion of the punching arm. For each punch, joint angles at $t = 0$, peak values and their timing, ranges within the punch, the mean elbow extension velocity (extension range divided by extension time), the time spent near full extension, and the time to 50% retraction were calculated. Analysis was descriptive; both punches are reported separately so that their consistency can be judged.

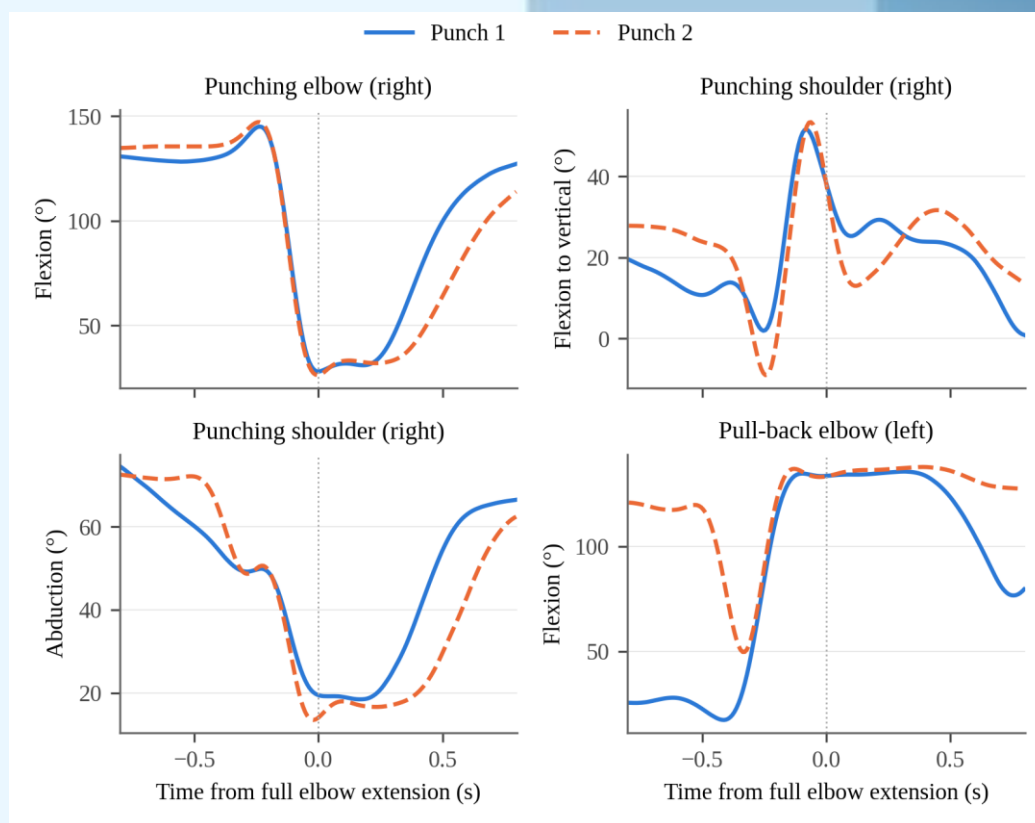
Results

Punching and Pull-Back Arms

The two punches were highly consistent (Figure 1, Table 1). The punching elbow was briefly cocked to 145.0° and 147.2° of flexion 0.24 s before the strike, then extended by 117.0° and 120.9° to 28.0° and 26.3° , an average of 488 and 504 $^\circ/\text{s}$. The punching shoulder rose forward to 51.6° and 53.4° of flexion 0.08 and 0.06 s before the strike, and it adducted from 64.6° and 72.2° of abduction in the guard to 19.6° and 13.9° at the strike, bringing the elbow into line behind the fist. The opposite (left) elbow, which was extended before the punch (17.4° and 49.8°), was pulled back to 133.6° and 133.3° of flexion; 90% of this pull-back was completed 0.18 s before the strike in both punches, the same instant at which the punching elbow began to extend. The punching arm stayed near full extension for 0.28 and 0.37 s and was 50% retracted 0.45 and 0.61 s after the strike.

Figure 1

Punching- and Pull-Back-Arm Kinematics in Two Fast Momtong Jireugi



Note. Right (punching) elbow flexion, right shoulder flexion relative to the vertical, right shoulder abduction, and left (pull-back) elbow flexion, aligned to full elbow extension of the punching arm ($t = 0$).

Table 1

Punching- and Pull-Back-Arm Kinematics in Two Fast Punches

Variable	Punch 1	Punch 2
Punching elbow, cocked flexion (°) / time (s)	145.0 / -0.24	147.2 / -0.24
Punching elbow at full extension (°)	28.0	26.3
Elbow extension range (°)	117.0	120.9
Mean elbow extension velocity (°/s)	488	504
Onset of elbow extension, 10% (s)	-0.18	-0.18
Punching shoulder flexion, peak (°) / time (s)	51.6 / -0.08	53.4 / -0.06
Punching shoulder abduction, guard → strike (°)	64.6 → 19.6	72.2 → 13.9
Pull-back elbow, extended → strike (°)	17.4 → 133.6	49.8 → 133.3
Pull-back 90% complete (s)	-0.18	-0.18
Time near full extension (s)	0.28	0.37
50% retraction after strike (s)	0.45	0.61

Note. Times relative to full elbow extension of the punching (right) arm (t = 0); negative = before. Shoulder flexion measured relative to the vertical.

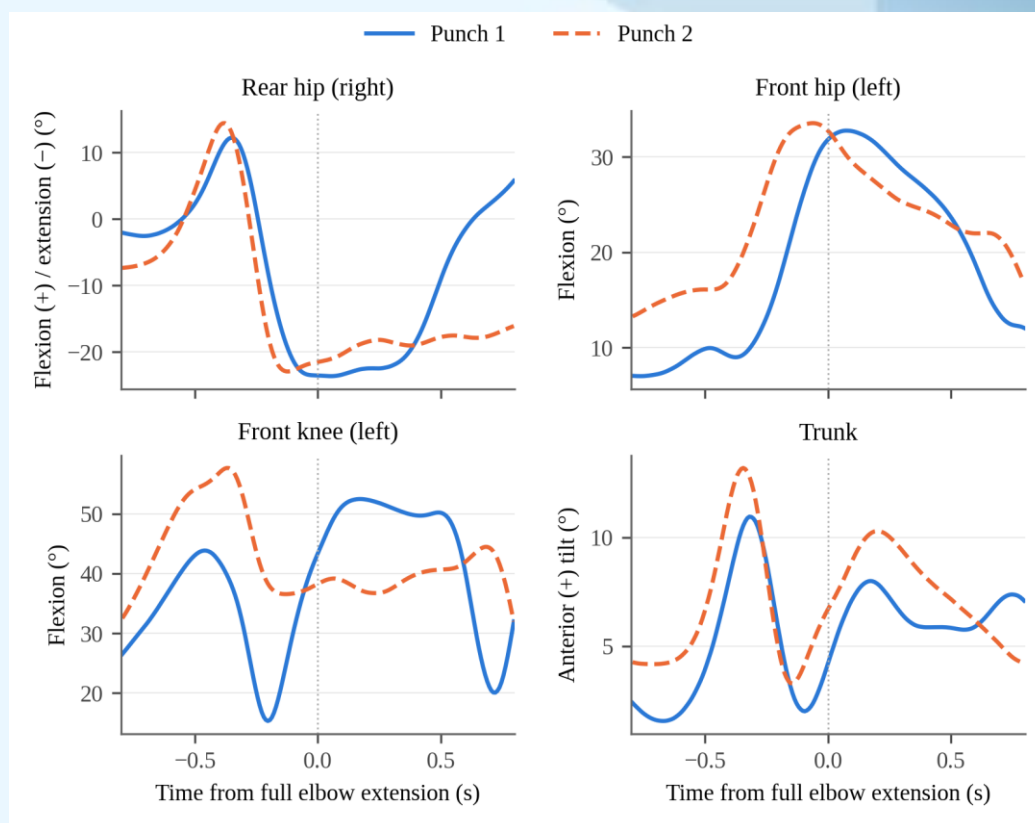
Lower Limbs and Trunk

The legs acted before the arms (Figure 2, Table 2). The rear (right) hip first flexed slightly (12.2° and 14.4°) 0.35 and 0.38 s before the strike and then extended by 35.8° and 37.3°; 90% of this extension was complete 0.11 and 0.19 s before the strike, reaching -23.5° and -21.5° at the strike. Meanwhile the front (left) hip flexed to 31.8° and 32.8°, the front knee remained flexed (43.1° and 38.2°), and the rear knee was flexed by 42.5° and 44.0°. Both hips were briefly abducted about 0.3 s before the strike and adducted to 5–10° at the strike. The trunk stayed close to

upright: anterior tilt was 4.1° and 6.6° at the strike, its range within the punch was 9.0° and 9.9° , and lateral flexion varied by only 6.5° and 6.4° .

Figure 2

Lower-Limb and Trunk Kinematics in Two Fast Momtong Jireugi



Note. Right (rear) hip flexion/extension, left (front) hip flexion, left knee flexion, and trunk anterior tilt, aligned to full elbow extension of the punching arm ($t = 0$).

Table 2

Lower-Limb and Trunk Kinematics in Two Fast Punches

Variable	Punch 1	Punch 2
Rear hip, peak flexion (°) / time (s)	12.2 / -0.35	14.4 / -0.38
Rear hip at strike (°)	-23.5	-21.5
Rear hip extension range (°)	35.8	37.3
Rear hip extension 90% complete (s)	-0.11	-0.19
Front hip flexion at strike (°)	31.8	32.8
Front knee flexion at strike (°)	43.1	38.2
Rear knee flexion at strike (°)	42.5	44.0
Rear ankle at strike (°)	24.8	13.7
Hip abduction, peak L / R (°)	35.1 / 25.9	38.9 / 33.5
Trunk anterior tilt at strike (°) / range (°)	4.1 / 9.0	6.6 / 9.9
Trunk lateral flexion range (°)	6.5	6.4

Note. Negative hip values = extension; positive ankle values = dorsiflexion.

Sequence of Events

Combining the two sets of results, the order of events was identical in both punches: start of rear-hip extension (-0.35 to -0.38 s), completion of the pull-back (-0.18 s) coinciding with the onset of punching-elbow extension (-0.18 s), completion of rear-hip extension (-0.19 to -0.11 s), peak punching-shoulder flexion (-0.08 to -0.06 s), and full elbow extension (0 s).

Discussion

This study provides, to the author's knowledge, the first whole-body kinematic description of the taekwondo Momtong Jireugi. Three findings stand out.

First, the punch followed a leg-first, arm-last order: the rear hip began to extend about a third of a second before the strike, and the elbow extended last. Second, the two arms were strictly coordinated: the pull-back of the opposite arm was completed exactly when the punching elbow started to extend. Third, the trunk remained nearly upright throughout.

Proximal-to-Distal Organization

The sequence from rear-hip extension through shoulder flexion to elbow extension is consistent with the proximal-to-distal pattern described for striking skills in general (Putnam, 1993) and for the karate reverse punch in particular (Vences Brito et al., 2011). In the present athlete, the brief cocking of the elbow (to 145–147°) and the slight rear-hip flexion before extension resemble counter-movements that precede the main action. The shoulder reached its peak flexion 0.06–0.08 s before the elbow finished extending, so the upper arm was already decelerating while the forearm completed the strike, as expected in a sequential chain.

Reciprocal Arm Action

The precise timing of the pull-back arm is a distinctive feature of the traditional taekwondo punch. In both punches, the opposite elbow reached 90% of its flexion at the same instant that the punching elbow began to extend. This suggests that the pull-back is not a simultaneous mirror of the punch but a preparatory action that is completed first. Whether this order improves punch speed or force, for example by contributing to trunk rotation, cannot be determined from kinematics alone and should be tested with force and pelvis-rotation data (Lenetsky et al., 2013).

Trunk Stability and Stance

The trunk tilted forward by no more than 7° at the strike and varied little in the frontal plane. An upright trunk is a basic requirement of poomsae technique, and the present data show that it can be maintained even at maximal speed. The adduction of both hips just before the strike indicates that the stance was closed or

adjusted during the punch; whether this reflects a step or a weight shift should be confirmed from the video and stance protocol.

Implications for Technique Teaching

The consistent events suggest six observable checkpoints for teaching the Momtong Jireugi (Table 3). They follow the order recorded here and can be checked by eye or with smartphone video. Selective feedback on a few such checkpoints, with attention directed to the effect of the movement, is consistent with principles of motor learning (Wulf et al., 2010).

Table 3

Observable Checkpoints for Teaching the Momtong Jireugi

Phase	Checkpoint	Reference value in this athlete
Preparation	1. Rear hip starts to extend before the arm moves	From 0.35–0.38 s before strike
Preparation	2. Opposite arm completes the pull-back first	90% complete at –0.18 s
Drive	3. Punching elbow stays in line (shoulder adducts)	Abduction 65–72° → 14–20°
Drive	4. Shoulder rises before the elbow finishes	Peak 52–53° at –0.08 to –0.06 s
Strike	5. Elbow extends last and fully	To 26–28°, ≈500 °/s
Strike	6. Trunk stays upright	≤7° anterior tilt

Note. Reference values describe one athlete at maximal speed and are examples, not norms.

Limitations

The findings are limited by (a) one athlete and two punches, which preclude generalization and statistical inference; (b) data digitized from software reports rather than raw marker trajectories, although agreement with reported extrema was

high; (c) problems in the report (a duplicated ankle plot, an implausible speed table, and implausible neck rotation), handled as described; (d) the absence of pelvis-rotation time series, force, or fist-velocity data, so the kinematics cannot be linked to punch effectiveness; and (e) an unconfirmed stance or step. Future studies should include several athletes of different levels, raw marker data including pelvis and trunk rotation, and a force target.

Conclusion

In a fast Momtong Jireugi, the athlete showed a clear leg-first, arm-last organization: rear-hip extension began about 0.35 s before the strike, the opposite arm completed its pull-back as the punching elbow began to extend, the punching shoulder rose and adducted, and the elbow extended last at about 500 °/s while the trunk remained upright. These consistent events provide measurable checkpoints for teaching the punch.

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