

Whole-Body Kinematics of the Slow-Tempo Momtong Jireugi in Taekwondo: A Single-Case 3D Motion-Capture Study for Technique Teaching

Alimbayeva Shakhzoda

Uzbek State University of Physical Education and Sport, Chirchik, Uzbekistan

Abstract

The middle-section punch (Momtong Jireugi) is traditionally taught at a slow tempo, with the fist held briefly at the target, before it is practiced at full speed. Whether such slow execution preserves the coordination expected of a straight punch has not been measured. This single-case study described the whole-body kinematics of a slow-tempo Momtong Jireugi and derived checkpoints for teaching. A 19-year-old male taekwondo athlete performed right-hand punches at a deliberately slow tempo while full-body kinematics were recorded with an optical motion-capture system (STT 3DMA, 19-marker model, 120 Hz). Two complete punches were analyzed after digitizing the joint-angle curves from the software report and aligning them to the instant the punching elbow reached 90% of its extension. Both punches showed the same order of events. The rear hip extended and the rear ankle plantarflexed (66–73° range) before the fist arrived. The opposite arm completed its pull-back (to 141–142° elbow flexion) 0.28–0.31 s before arrival, when the punching elbow began to extend. The punching shoulder adducted from 59–70° to 22°, and the elbow extended by 116–118° to 26–27° (main phase 0.24–0.30 s). The fist was then held for 0.48–0.77 s, and the trunk stayed upright (anterior tilt 2–7°). The slow drill thus preserved a leg-first, pull-back-then-punch order and added a deliberate hold. Six teaching checkpoints are proposed. Because the data come from one athlete and two punches, the findings are exploratory.

Keywords: taekwondo; Momtong Jireugi; slow tempo; punch; kinematics; 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). Skilled karate 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 punch force depends on the contribution of the legs and trunk as well as the arm (Lenetsky et al., 2013).

In taekwondo, the middle-section punch (Momtong Jireugi) is among the first techniques taught and a core element of poomsae. Beginners and athletes refining their technique commonly practice it at a slow tempo: the punch is delivered deliberately, the fist is held at the target, and the opposite arm is pulled back to the hip. The rationale is that the slow drill lets the learner and coach see and correct each part of the movement. This rationale rests on an untested assumption, namely that the slow drill preserves the order of segment actions of a real punch. No study was found that measured the whole-body kinematics of a slow-tempo Momtong Jireugi.

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

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 a deliberately slow tempo, holding the fist briefly at full extension, as in a technique-learning drill. The recording lasted 140 s; the analysis window (99.8–105.7 s) contained two complete right-hand punches and the start of a third, which was incomplete and excluded. 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, applied the axis scales, and traced each curve by color. Agreement with the 38 extrema reported by the software was good (median absolute difference 0.46° , mean 1.1°); the largest deviations occurred at the edges of the plotted window, outside the analyzed punches. Curves were resampled to 120 Hz and smoothed with a Savitzky–Golay filter (13 points, third order).

Two problems in the report were handled. First, the plot labeled right ankle in the lower-limb section was an exact copy of the right knee plot (identical image checksum); the right ankle curve was therefore taken from the full-body section. Second, neck rotation showed a range of $113\text{--}123^\circ$ within each punch, which is implausible for this technique and probably reflects the model's head–trunk reference or marker occlusion; neck rotation was therefore not interpreted.

Events and Variables

Because the slow punch included a hold at full extension, the strike instant was defined as the moment the punching elbow reached 90% of its extension (arrival, $t = 0$). The following events were identified: peak rear-hip flexion and peak rear-ankle dorsiflexion (start of the leg action), maximal extension of the opposite elbow before the pull-back, 90% completion of the pull-back, the elbow position in guard, 10% onset of punching-elbow extension, the end of the hold (elbow flexing again by 10% of its range), and 50% retraction. Joint angles at $t = 0$, peak values and their timing, and ranges within each punch were calculated. Analysis was descriptive; both punches are reported separately so that their consistency can be judged.

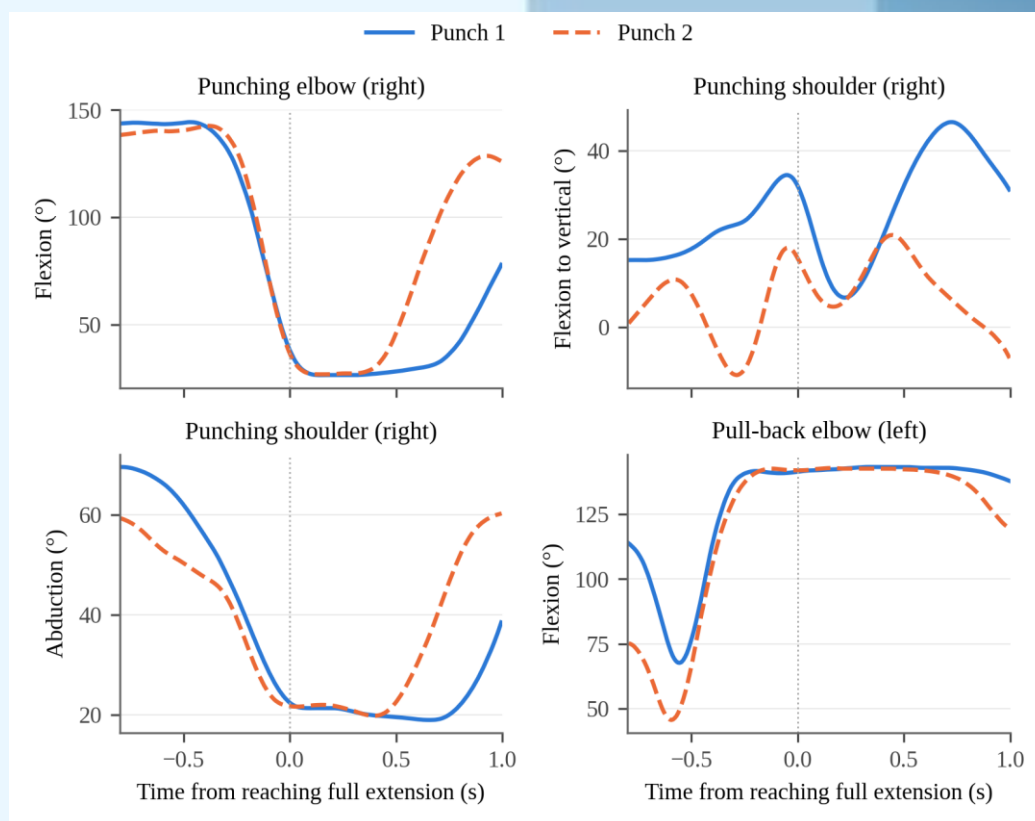
Results

Punching and Pull-Back Arms

The two punches showed the same arm pattern (Figure 1, Table 1). The opposite (left) elbow was extended to 67.6° and 45.6° about 0.55 and 0.59 s before arrival and then pulled back to $141\text{--}142^\circ$ of flexion; 90% of this pull-back was complete at -0.31 and -0.28 s. The punching elbow began to extend at almost the same instant (10% onset at -0.30 and -0.24 s). From a guard position of 144.4° and 142.6° , it extended by 118.0° and 115.9° to 26.4° and 26.8° ; the main extension (10–90%) lasted 0.30 and 0.24 s, a mean of 315 and 384 $^\circ/\text{s}$. During the extension the punching shoulder adducted from 69.6° and 59.3° to 22.3° and 21.8° of abduction. The fist was held at full extension for 0.77 and 0.48 s, and the elbow was 50% retracted 1.03 and 0.65 s after arrival. Forward flexion of the punching shoulder was variable between the two punches and was not interpreted further.

Figure 1

Punching- and Pull-Back-Arm Kinematics in Two Slow-Tempo 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 the instant the punching elbow reached 90% of its extension ($t = 0$).

Table 1

Punching- and Pull-Back-Arm Kinematics in Two Slow-Tempo Punches

Variable	Punch 1	Punch 2
Pull-back elbow, extended (°) / time (s)	67.6 / -0.55	45.6 / -0.59
Pull-back 90% complete (s)	-0.31	-0.28
Pull-back elbow at arrival (°)	141.4	142.0
Punching elbow in guard (°)	144.4	142.6
Onset of punching-elbow extension, 10% (s)	-0.30	-0.24
Elbow extension range (°) / minimum (°)	118.0 / 26.4	115.9 / 26.8
Main extension time, 10–90% (s)	0.30	0.24
Mean extension velocity, 10–90% (°/s)	315	384
Punching shoulder abduction, guard → arrival (°)	69.6 → 22.3	59.3 → 21.8
Hold at full extension (s)	0.77	0.48
50% retraction after arrival (s)	1.03	0.65

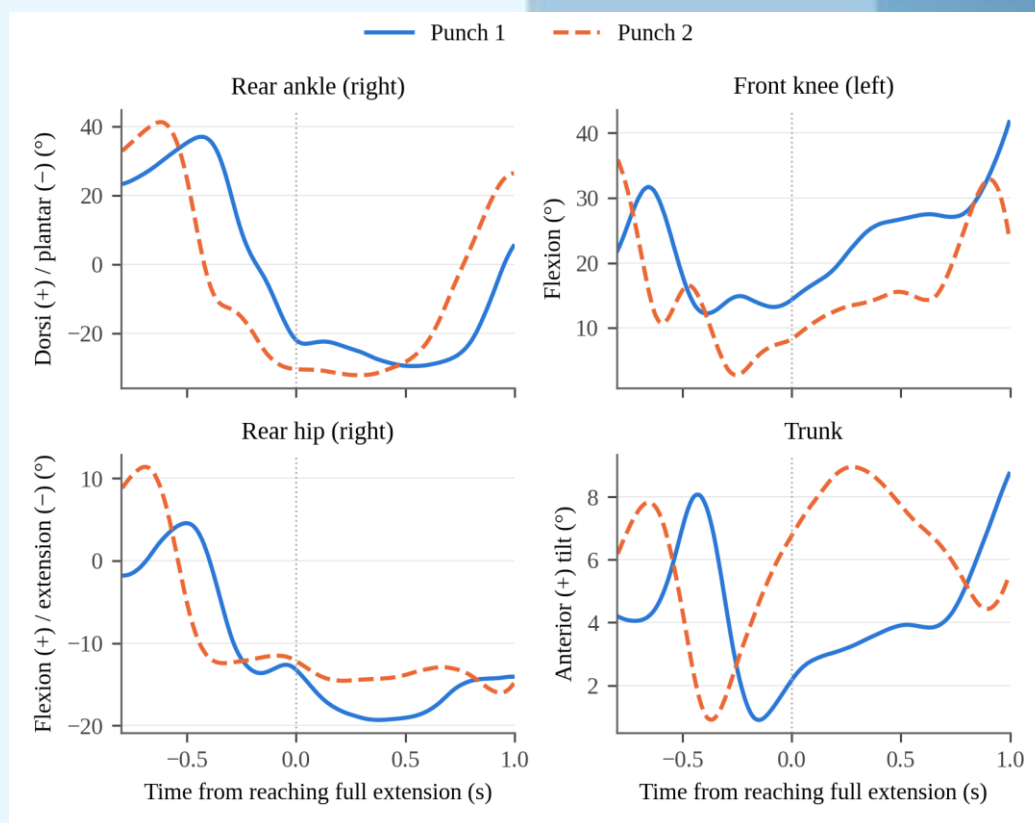
Note. $t = 0$ when the punching (right) elbow reached 90% of its extension; negative = before.

Legs and Trunk

The legs acted before the fist arrived (Figure 2, Table 2). The rear (right) hip extended from 4.6° and 11.4° of flexion at -0.50 and -0.69 s to about -12° by -0.3 s and was at -13.3° and -12.1° at arrival. The rear ankle moved from 37.0° and 41.3° of dorsiflexion (at -0.43 and -0.62 s) to 22.0° and 30.3° of plantarflexion at arrival, indicating that the rear heel was raised. At arrival the front (left) knee was nearly extended (14.4° and 8.2°) and the rear knee flexed (39.5° and 30.2°). The trunk stayed close to upright: anterior tilt was 2.2° and 6.7° at arrival, its range within the punch was 7.2° and 8.1° , and lateral flexion varied by 4.3° and 8.4° .

Figure 2

Lower-Limb and Trunk Kinematics in Two Slow-Tempo Momtong Jireugi



Note. Right (rear) ankle, left (front) knee, right (rear) hip, and trunk anterior tilt, aligned to the instant the punching elbow reached 90% of its extension ($t = 0$).

Table 2

Lower-Limb and Trunk Kinematics in Two Slow-Tempo Punches

Variable	Punch 1	Punch 2
Rear hip, peak flexion (°) / time (s)	4.6 / -0.50	11.4 / -0.69
Rear hip at arrival (°)	-13.3	-12.1
Rear ankle, peak dorsiflexion (°) / time (s)	37.0 / -0.43	41.3 / -0.62
Rear ankle at arrival (°)	-22.0	-30.3
Rear ankle range (°)	66.4	73.3
Front knee flexion at arrival (°)	14.4	8.2
Rear knee flexion at arrival (°)	39.5	30.2
Front hip flexion at arrival (°)	13.3	13.9
Trunk anterior tilt at arrival (°) / range (°)	2.2 / 7.2	6.7 / 8.1
Trunk lateral flexion range (°)	4.3	8.4

Note. Negative hip values = extension; negative ankle values = plantarflexion.

Sequence of Events

In both punches the order of events was the same: rear-hip flexion peak and rear-ankle dorsiflexion peak (-0.69 to -0.43 s), most of the rear-hip extension (by about -0.3 s), completion of the pull-back together with the onset of punching-elbow extension (-0.31 to -0.24 s), arrival at full extension (0 s), a hold of about half a second or more, and retraction.

Discussion

This study provides, to the author's knowledge, the first whole-body kinematic description of a slow-tempo Momtong Jireugi. Three findings stand out. First, the slow drill preserved a leg-first, arm-last order. Second, the pull-back of the opposite arm was completed before the punching elbow started to extend. Third, the

slow drill differed from a real punch mainly by a deliberate hold at full extension, while the trunk remained upright throughout.

Does the Slow Drill Preserve the Structure of the Punch?

The order observed here, with the rear hip and ankle acting before the arm and the elbow extending last, is consistent with the proximal-to-distal organization of striking skills (Putnam, 1993) and of the karate reverse punch (Vences Brito et al., 2011). The main extension of the elbow lasted only 0.24–0.30 s, so the slow tempo was achieved mostly by the preparation and by the hold rather than by extending the elbow slowly. This suggests that the slow drill keeps the essential sequence of the punch and lengthens the phases in which positions can be observed and corrected.

Reciprocal Arm Action

In both punches, the pull-back of the opposite arm reached 90% of its range at the moment the punching elbow began to extend. The pull-back therefore acts as a preparatory action that is completed first rather than a simultaneous mirror of the punch. This ordering can be taught explicitly in the slow drill. Whether it contributes to punch speed or force, for example through trunk rotation, requires force and pelvis-rotation data (Lenetsky et al., 2013).

Legs and Trunk

The large plantarflexion of the rear ankle, indicating a raised rear heel, and the extension of the rear hip before arrival show that the lower limbs participated even at a slow tempo. The trunk tilted forward by no more than 7° and varied little in the frontal plane, meeting the upright-posture requirement of poomsae technique. The nearly straight front knee at arrival may reflect the stance used in this drill and should be interpreted together with the stance protocol.

Implications for Technique Teaching

The consistent events suggest six observable checkpoints for teaching the slow-tempo Momtong Jireugi (Table 3). They can be checked by eye or with smartphone video, and selective feedback on a few such points is consistent with

principles of motor learning (Wulf et al., 2010). Once these checkpoints are stable, the hold can be shortened and the tempo increased toward competition speed.

Table 3

Observable Checkpoints for Slow-Tempo Teaching of the Momtong Jireugi

Phase	Checkpoint	Reference value in this athlete
Preparation	1. Rear hip extends and rear heel rises before the arm moves	Rear ankle to -22° to -30° at arrival
Preparation	2. Opposite arm finishes the pull-back first	90% complete at -0.31 to -0.28 s
Drive	3. Punching elbow stays in line (shoulder adducts)	Abduction $59-70^{\circ} \rightarrow 22^{\circ}$
Strike	4. Elbow extends last and fully	To $26-27^{\circ}$
Hold	5. Fist held still at full extension	0.5–0.8 s
Whole action	6. Trunk stays upright	$\leq 7^{\circ}$ anterior tilt

Note. Reference values describe one athlete at a slow tempo 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; (c) problems in the report (a duplicated ankle plot and implausible neck rotation), handled as described; (d) the absence of pelvis-rotation time series, force, or fist-velocity data; and (e) no fast-tempo comparison within this study. A direct comparison of slow and fast punches in the same athletes would show which features of the slow drill transfer to competition speed.

Conclusion

In a slow-tempo Momtong Jireugi, the athlete preserved a leg-first, arm-last order: the rear hip extended and the rear heel rose before the fist arrived, the opposite arm completed its pull-back as the punching elbow began to extend, the punching shoulder adducted, and the elbow extended last, followed by a deliberate hold, while the trunk remained upright. These consistent events provide measurable checkpoints for teaching the punch at a slow tempo before progressing to full speed.

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