

WHOLE-BODY KINEMATICS OF A SLOW-TEMPO TAEKWONDO ROUNDHOUSE KICK (DOLLYO CHAGI): A SINGLE-CASE 3D MOTION- CAPTURE STUDY FOR TECHNIQUE TEACHING

Shoxrux B. Elboyev

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

Abstract

The roundhouse kick (Dollyo Chagi) is the principal scoring technique in Olympic taekwondo and is commonly taught through slow-tempo repetitions, yet the whole-body kinematics of such slow execution have not been described. This single-case study aimed to describe the lower-limb, trunk, head, and arm kinematics of a slow-tempo Dollyo Chagi and to derive observable checkpoints for technique teaching. A 19-year-old male taekwondo athlete performed right-leg roundhouse kicks 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 consecutive kicks were analyzed after digitizing the joint-angle curves from the software report (mean absolute difference from reported extrema 0.66°) and aligning them to full knee extension. Both kicks followed the same sequence: ankle plantarflexion began 0.54–0.61 s before extension, the knee reached its chamber ($119\text{--}121^\circ$) 0.30–0.32 s before extension, thigh elevation peaked 0.22–0.24 s before extension, and the knee then extended by about 114° in 0.30–0.32 s (mean $357\text{--}383^\circ/\text{s}$) while hip abduction was held at $53\text{--}57^\circ$. At extension the trunk leaned $45\text{--}46^\circ$ away from the target, the head had already rotated toward the target, the opposite arm reached peak abduction ($79\text{--}84^\circ$), the guard arm moved little, and the support knee was fully extended. The slow-tempo kick thus preserved the proximal-to-distal organization described for fast kicks and showed a coordinated upper-body counterbalance. Eight teaching checkpoints are proposed. Because the data come from one athlete and two kicks, the findings are exploratory.

Keywords: taekwondo; roundhouse kick; Dollyo Chagi; kinematics; motion capture; technique teaching; single-case study

Introduction

The roundhouse kick (Dollyo Chagi, also called Bandal Chagi) is the most frequently used scoring technique in Olympic taekwondo. Biomechanical research has shown that its speed arises from a throw-like, proximal-to-distal sequence in which hip flexion precedes knee extension (Kim et al., 2011), that its execution time and impact force depend on target distance and competitive experience (Falco et al., 2009; Estevan et al., 2011), and that the pivot hip, trunk, and pelvis adjust their motion to the distance of the target (Kim et al., 2010). Comparable proximal-to-distal patterns have been reported for other martial arts kicks (Sørensen et al., 1996), and the whole-body organization of the roundhouse kick differs even among expert practitioners of different martial arts (Gavagan & Sayers, 2017).

Almost all of this evidence concerns kicks executed at maximal speed. In daily practice, however, coaches frequently teach and correct the Dollyo Chagi through slow-tempo repetitions, in which the athlete moves deliberately through each phase so that the position of every segment can be observed and corrected. The value of such drills depends on whether the slow kick preserves the essential structure of the fast one. If the order of segment actions and the key positions are preserved, slow-tempo practice can serve as a template; if they are not, it may rehearse a different movement. No study was found that described the whole-body kinematics of a slow-tempo roundhouse kick, including the trunk, head, and arms, which carry the balance and guard demands of the technique.

The aims of this single-case study were therefore (a) to describe the kinematics of the kicking leg, support leg, trunk, head, and arms during a slow-tempo Dollyo Chagi, (b) to establish the timing of key events relative to the strike, and (c) to derive observable checkpoints that coaches can use when teaching the kick.

Materials and Methods

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 0.66° , median 0.58°). Curves were resampled to 120 Hz and smoothed with a Savitzky–Golay filter (13 points, third order).

Two export errors 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 (identical image checksum); the right ankle curve was therefore taken from the full-body section of the report. Second, the software’s gait-analysis table listed a maximum right knee angular speed of $314^\circ/\text{s}$, which is lower than the mean knee extension velocity visible in its own angle curve ($357\text{--}383^\circ/\text{s}$); because that table is computed by a module designed for running and walking, its values were not used.

Events and Variables

Full knee extension of the kicking leg (minimum knee flexion between the chamber and re-chamber peaks) was taken as the strike instant ($t = 0$). The following events were identified: onset of ankle plantarflexion, knee chamber (peak knee flexion before extension), peak thigh elevation (hip flexion relative to the vertical), and re-chamber (peak knee flexion after extension). For each kick, joint angles at $t = 0$, peak values and their timing, ranges within the kick, and the mean knee extension velocity (extension range divided by extension time) were calculated. Given the single-case design and two trials, analysis was descriptive; both kicks are reported separately so that their consistency can be judged.

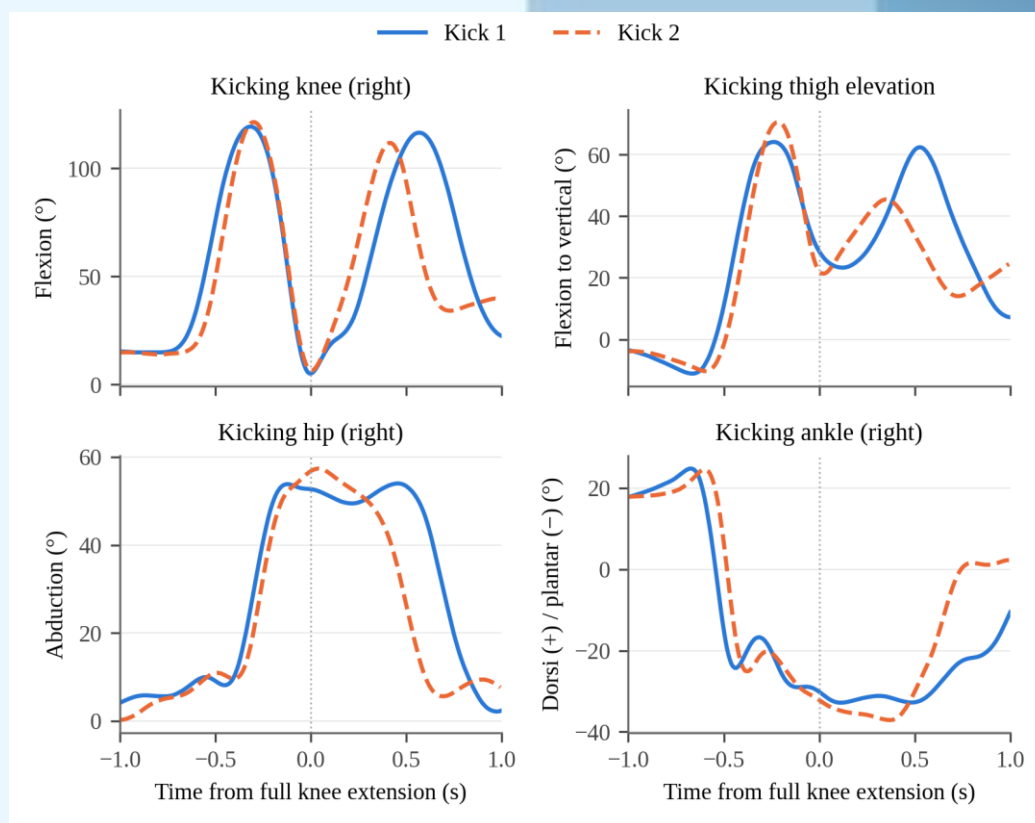
Results

Kicking and Support Leg

The two kicks showed the same sequence and similar magnitudes (Figure 1, Table 1). Ankle plantarflexion was the first identifiable action, beginning 0.54–0.61 s before extension and reaching -30° to -32° at the strike. The knee reached the chamber (119.3° and 121.4°) 0.32 and 0.30 s before extension, and thigh elevation peaked shortly afterwards (64.1° and 70.6° , at -0.24 and -0.22 s). The knee then extended by 114.2° and 114.9° in 0.32 and 0.30 s, a mean extension velocity of 357 and 383 $^{\circ}/\text{s}$, to 5.1° and 6.5° of flexion. Hip abduction rose during the chamber and remained on a plateau of about 50 – 57° throughout the extension (52.7° and 56.8° at $t = 0$). The leg was re-chambered 0.57 and 0.42 s after extension, giving chamber-to-re-chamber times of 0.89 and 0.72 s. The support knee reached its most extended position at the strike (1.8° and -14.5°), and the support hip was abducted by 51 – 55° .

Figure 1

Kicking-Leg Kinematics in Two Slow-Tempo Dollyo Chagi Kicks



Note. Right knee flexion, thigh elevation (hip flexion relative to the vertical), hip abduction, and ankle angle, aligned to full knee extension ($t = 0$).

Table 1

Kicking- and Support-Leg Kinematics in Two Slow-Tempo Kicks

Variable	Kick 1	Kick 2
Ankle plantarflexion onset (s)	-0.61	-0.54
Knee chamber, peak flexion (°) / time (s)	119.3 / -0.32	121.4 / -0.30
Thigh elevation, peak (°) / time (s)	64.1 / -0.24	70.6 / -0.22
Knee extension range (°) / duration (s)	114.2 / 0.32	114.9 / 0.30
Mean knee extension velocity (°/s)	357	383
Knee flexion at extension (°)	5.1	6.5
Hip abduction at extension (°)	52.7	56.8
Ankle angle at extension (°)	-30.2	-32.2
Re-chamber time after extension (s)	0.57	0.42
Chamber to re-chamber (s)	0.89	0.72
Support knee flexion at extension (°)	1.8	-14.5
Support hip abduction at extension (°)	51.4	54.7

Note. Times relative to full knee extension ($t = 0$); negative = before. Negative ankle values = plantarflexion.

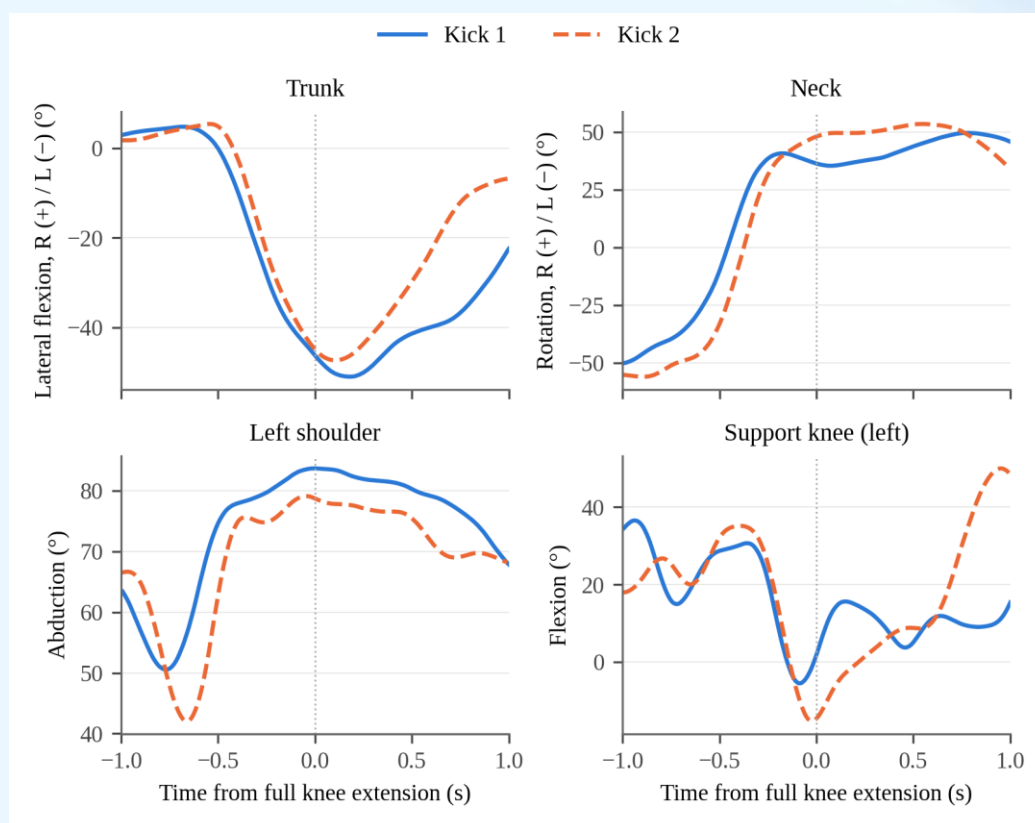
Trunk, Head, and Arms

The upper body showed an equally consistent pattern (Figure 2, Table 2). The trunk leaned away from the kick, reaching 46.2° and 44.9° of left lateral flexion at the strike and a peak of 50.9° and 47.3° shortly afterwards (+0.18 and +0.10 s), while anterior–posterior tilt remained small (3.9° and 6.2° at $t = 0$). The neck rotated through 100–110° during each kick; most of this rotation was completed about 0.2 s before extension, and the neck was flexed by 37–39° at the strike. The left arm, on the side opposite the kick, was elevated as the leg chambered, reaching peak

abduction exactly at or just before the strike (83.7° at 0.00 s and 79.1° at -0.05 s), with an elbow range of 87° . The right arm stayed close to the guard position: its elbow range was only 9.7° and 13.9° , and its shoulder abduction range 18.4° and 21.2° .

Figure 2

Trunk, Head, Arm, and Support-Knee Kinematics in Two Slow-Tempo Dollyo Chagi Kicks



Note. Trunk lateral flexion, neck rotation, left shoulder abduction, and left (support) knee flexion, aligned to full knee extension of the kicking leg ($t = 0$).

Table 2

Trunk, Head, and Arm Kinematics in Two Slow-Tempo Kicks

Variable	Kick 1	Kick 2
Trunk lateral flexion at extension (°)	-46.2	-44.9
Trunk lateral flexion, peak (°) / time (s)	-50.9 / +0.18	-47.3 / +0.10
Trunk anterior tilt at extension (°)	3.9	6.2
Neck rotation range (°)	100.2	109.7
Neck rotation at extension (°)	36.4	48.2
Neck flexion at extension (°)	38.7	37.1
Left shoulder abduction, peak (°) / time (s)	83.7 / 0.00	79.1 / -0.05
Left elbow range (°)	87.1	87.0
Right elbow range (°)	9.7	13.9
Right shoulder abduction range (°)	18.4	21.2

Note. Negative lateral flexion = lean to the left (away from the right-leg kick).
Ranges computed within each kick window.

Discussion

This study described, to the author's knowledge for the first time, the whole-body kinematics of a slow-tempo Dollyo Chagi. Three findings stand out. First, the slow kick preserved a clear proximal-to-distal organization of the kicking leg. Second, hip abduction was held rather than released while the knee extended. Third, the strike was accompanied by a coordinated upper-body counterbalance: trunk lean away from the target, early head rotation toward it, and elevation of the opposite arm timed to the strike, while the guard arm remained still.

Kicking-Leg Sequence

In both kicks the thigh was elevated and the knee chambered before the knee extended, the order that underlies the throw-like mechanism of the roundhouse kick (Kim et al., 2011) and of other martial arts kicks (Sørensen et al., 1996). The fact that this order was maintained at a deliberately slow tempo supports the use of slow repetitions to rehearse the structure of the kick. The mean knee extension velocity of 357–383 °/s is, as expected, a slow execution; the present data cannot show how the sequence changes when speed is maximal, and whether the timing between events scales proportionally remains to be tested. Early ankle plantarflexion, well before the chamber, indicates that the athlete prepared the striking surface of the instep early rather than at the end of the extension.

The hip-abduction plateau during extension is a practically important detail. Because the roundhouse kick travels on a horizontal arc, a stable abducted hip keeps the shank in the plane of the target while the knee extends. Kim et al. (2010) showed that the pivot hip, pelvis, and trunk adapt to target distance; the present data add that, at a fixed slow tempo, the kicking hip maintains its abduction throughout the strike.

Upper-Body Counterbalance and Support

The large lateral trunk lean (45–51°) and the opposite-arm elevation are consistent with the need to keep the center of mass over a narrow single-leg base while the kicking leg is raised and extended. The head behaved differently from the trunk: it rotated toward the target early and stayed there, which suggests that gaze on the target was secured before the strike. The support knee was fully extended at the strike, which provides a stable base. In kick 2 the support knee reached –14.5°, indicating extension beyond the model's neutral reference, which may reflect true knee hyperextension or a marker artefact and should be checked in future recordings.

Implications for Technique Teaching

The consistent events suggest eight observable checkpoints for slow-tempo teaching of the Dollyo Chagi (Table 3). Their order follows the sequence recorded

here, and each can be checked by a coach by eye or with a smartphone video. Providing learners with selective, externally focused feedback on such checkpoints is consistent with principles of motor learning (Wulf et al., 2010). Once the sequence is stable, tempo should be increased progressively, because the demands of competition, including distance and time pressure, influence kick execution (Falco et al., 2009; Estevan et al., 2011).

Table 3

Observable Checkpoints for Slow-Tempo Teaching of the Dollyo Chagi

Phase	Checkpoint	Reference value in this athlete
Preparation	1. Instep prepared (ankle pointed) before the knee lifts	Plantarflexion from 0.54–0.61 s before strike
Preparation	2. Head turned to the target before the leg extends	Most of 100–110° rotation done by –0.2 s
Chamber	3. Full knee chamber	≈120° knee flexion
Chamber	4. Thigh raised before extension starts	64–71° thigh elevation
Extension	5. Hip stays abducted while the knee extends	≈50–57° throughout extension
Extension	6. Trunk leans away without collapsing forward	45–46° lateral, 4–6° forward
Strike	7. Opposite arm raised at contact; kicking-side arm keeps guard	79–84° vs ≈10–14° elbow range
Strike	8. Support knee extended at contact	≈0° knee flexion

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 kicks, which preclude generalization and statistical inference; (b) a slow tempo only, without a maximal-speed comparison; (c) data digitized from software reports rather than raw marker trajectories, although agreement with the reported extrema was high; (d) two export errors in the report, handled as described; and (e) the absence of a target, force, or foot-velocity measurement, so the kinematics cannot be linked to kick effectiveness. Future studies should compare slow and fast kicks within the same athletes, include several athletes of different levels, and add foot velocity and impact force.

Conclusion

In a slow-tempo Dollyo Chagi, the athlete preserved the proximal-to-distal organization of the kicking leg, held hip abduction through knee extension, and balanced the strike with a lateral trunk lean, early head rotation toward the target, opposite-arm elevation, a stable guard arm, and an extended support knee. These consistent events provide a set of checkpoints for teaching the kick at slow tempo before progressing to competition speed.

References

- Bates, B. T. (1996). Single-subject methodology: An alternative approach. *Medicine and Science in Sports and Exercise*, 28(5), 631–638.
<https://doi.org/10.1097/00005768-199605000-00016>
- Estevan, I., Álvarez, O., Falco, C., Molina-García, J., & Castillo, I. (2011). Impact force and time analysis influenced by execution distance in a roundhouse kick to the head in taekwondo. *Journal of Strength and Conditioning Research*, 25(10), 2851–2856. <https://doi.org/10.1519/JSC.0b013e318207ef72>
- Falco, C., Alvarez, O., Castillo, I., Estevan, I., Martos, J., Mugarra, F., & Iradi, A. (2009). Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. *Journal of Biomechanics*, 42(3), 242–248.
<https://doi.org/10.1016/j.jbiomech.2008.10.041>

- Gavagan, C. J., & Sayers, M. G. L. (2017). A biomechanical analysis of the roundhouse kicking technique of expert practitioners: A comparison between the martial arts disciplines of Muay Thai, Karate, and Taekwondo. *PLoS ONE*, 12(8), Article e0182645. <https://doi.org/10.1371/journal.pone.0182645>
- Kim, J.-W., Kwon, M.-S., Yenuga, S. S., & Kwon, Y.-H. (2010). The effects of target distance on pivot hip, trunk, pelvis, and kicking leg kinematics in Taekwondo roundhouse kicks. *Sports Biomechanics*, 9(2), 98–114. <https://doi.org/10.1080/14763141003799459>
- Kim, Y. K., Kim, Y. H., & Im, S. J. (2011). Inter-joint coordination in producing kicking velocity of Taekwondo kicks. *Journal of Sports Science and Medicine*, 10(1), 31–38.
- Sørensen, H., Zacho, M., Simonsen, E. B., Dyhre-Poulsen, P., & Klausen, K. (1996). Dynamics of the martial arts high front kick. *Journal of Sports Sciences*, 14(6), 483–495. <https://doi.org/10.1080/02640419608727735>
- Wulf, G., Shea, C., & Lewthwaite, R. (2010). Motor skill learning and performance: A review of influential factors. *Medical Education*, 44(1), 75–84. <https://doi.org/10.1111/j.1365-2923.2009.03421.x>