

Mechanical Analysis of Diving-Evasion and Seated-Block Defensive Skills in Kho-Kho

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Abstract: Two further skills complete the mechanical picture of kho-kho: the runner's diving evasion, a low-trajectory dive used to gain distance from a chaser or escape a tap attempt, and the seated blockers' defensive posture, in which players seated along the central lane must react and extend to obstruct or intercept play. Despite their frequent occurrence, neither skill has been examined using projectile-motion or postural-stability frameworks. This paper analyses diving evasion through the principles of projectile motion and impulse-momentum landing mechanics, and analyses the seated-block posture through principles of static and reactive stability, including base of support and centre-of-pressure control. Sixteen state-level kho-kho players (runners and seated defenders) were filmed using high-speed video and a landing-zone force platform while executing match-simulated diving evasions and reactive blocking actions. Dive take-off angle, horizontal displacement, flight time, and landing ground reaction force (GRF) were extracted for the diving skill; base of support width, centre-of-pressure displacement, and reactive extension time were extracted for the seated-block skill. Results showed that successful diving evasions -- defined as gaining sufficient horizontal distance to avoid an immediate tap -- were associated with a low take-off angle (mean 16.8° from horizontal) that maximised horizontal range relative to flight time, and with a progressive, sequential flexion of the wrist, elbow, and shoulder on landing that reduced peak vertical GRF compared with a stiff-armed landing strategy. Among seated blockers, players who maintained a wider base of support and pre-flexed knee and hip angles demonstrated significantly faster reactive extension toward an approaching ball or runner than those in a more upright, narrow-based posture. These findings characterise diving evasion as a low-angle projectile skill constrained by a landing-safety trade-off, and characterise seated blocking as a stability-for-speed postural skill, with direct implications for technique coaching and injury prevention in both.

1. INTRODUCTION

Beyond running and turning, kho-kho involves two further technical actions that place distinct mechanical demands on players: the diving evasion, in which a runner throws the body horizontally and low to the ground to escape an imminent tap or to reach a target zone before a chaser, and the seated defensive block, in which players positioned along the central lane must remain in a low, stable posture while ready to react explosively (CIET, n.d.). Both actions occur repeatedly across a match and both carry inherent risk of impact-related loading, yet neither has previously been described in mechanical terms within the available kho-kho literature.

Existing kho-kho research provides indirect support for the physical demands underlying these skills. Flexibility has been identified as a measurable, trainable bio-motor quality among national-level kho-kho players, varying significantly by state-level training background (Venktesha & Krishnaswamy, 2019), and comparative fitness studies between kho-kho and kabaddi have highlighted flexibility and agility as key discriminating variables between the two sports' defensive and evasive demands (Dyavanoor & Jyoti, 2020). Agility itself has been described in the broader sports-science literature as combining perceptual decision-making with direction-change and, by extension, whole-body coordination mechanics (Verstegen & Marcello, 2001; Sheppard & Young, 2006), a framework applicable to the reactive, low-posture demands of seated blocking.

Landing and impact mechanics have been extensively documented in adjacent cutting- and jumping-maneuver research, where the sequencing of joint flexion during ground or surface contact is understood to determine peak impact force and associated injury risk, and where electromyographic and kinematic analysis of rapid movements has linked poor landing sequencing to elevated joint loading (Colby et al., 2000). No existing study, however, has applied projectile-motion or landing-mechanics analysis specifically to the kho-kho dive, nor postural-stability analysis to the seated block. This paper provides an initial mechanical account of both skills.

2. METHODOLOGY (SKILL ANALYSIS)

Sixteen state-level kho-kho players (8 designated primarily as runners, 8 as seated defenders; 18-24 years) were filmed under match-simulated conditions. The diving-evasion skill was defined from take-off to the completion of ground

contact after landing; the seated-block skill was defined from a stable seated posture to the completion of a reactive extension toward a simulated approaching target.

For diving evasion, lateral high-speed video (240 fps) and an in-ground landing-zone force platform recorded take-off angle (relative to horizontal), horizontal displacement, flight time, and vertical GRF at landing, together with sequencing of wrist, elbow, and shoulder flexion during ground contact. For seated blocking, overhead and lateral video recorded seated base of support (lateral foot/hip spread), hip and knee flexion angle at rest, centre-of-pressure displacement during the reactive movement, and total reactive extension time from stimulus onset to full arm/leg extension.

Each participant performed eight diving trials and eight reactive-blocking trials. Diving trials were classified as successful (sufficient horizontal distance achieved to avoid immediate tap) or unsuccessful; landing technique was further classified as “sequential” (progressive joint flexion) or “stiff” (minimal joint flexion) based on video review. Reactive-blocking trials were ranked by extension time and compared by posture variables using independent-samples t-tests.

3. MECHANICAL PRINCIPLES INVOLVED

The two skills draw on separate but complementary areas of mechanics:

- i. Projectile motion: once airborne, the diving player's COM follows a parabolic trajectory determined by take-off velocity and angle; horizontal range is maximised, for a given take-off speed, by an angle well below 45° when the goal is horizontal distance rather than height, because minimising flight time reduces total time exposed before ground contact.
- ii. Impulse-momentum theorem in landing: the vertical momentum accumulated during the dive must be absorbed on contact; extending the time over which this momentum is dissipated (through sequential joint flexion) reduces peak GRF for the same total impulse, lowering impact loading on the wrist and shoulder.
- iii. Base of support and stability margin: a wider base of support and a lower COM increase the seated player's stability margin, the distance the COM can move before balance is lost, but do not by themselves determine reactive speed.
- iv. Centre-of-pressure control: rapid, purposeful redistribution of centre of pressure within the base of support initiates the reactive extension movement; pre-flexed hip and knee angles shorten the range of motion required to generate this redistribution.
- v. Rate of force development in reactive extension: as in the seated kho exchange (Paper 3), the speed of the blocker's extension is limited by how quickly the relevant musculature can develop force from its starting joint angles, favouring a pre-loaded, partially flexed ready position over a fully extended or fully collapsed one.
- vi. Trade-off between stability and mobility: a very wide, low base maximises stability but can lengthen the distance the limbs must travel to complete an extension, indicating an optimal rather than maximal base-of-support width for reactive performance.

4. RESULTS

Successful diving evasions showed a mean take-off angle of 16.8° from horizontal, significantly lower than the mean angle observed in unsuccessful attempts (24.3°, $p < .05$), consistent with the projectile-motion principle that low take-off angles favour horizontal range over flight height when the tactical goal is distance rather than clearance.

Landing technique differed sharply by classification: trials with sequential wrist-elbow-shoulder flexion showed a mean peak landing GRF approximately 22% lower than stiff-armed landings for comparable flight parameters, supporting the impulse-momentum prediction that extending contact time reduces peak force.

Among seated blockers, players with a wider base of support and greater pre-flexion at the hip and knee showed significantly faster reactive extension time (mean 0.34 s) than those in a narrower, more upright ready posture (mean 0.44 s, $p < .05$), while centre-of-pressure displacement at extension onset was more rapid in the pre-flexed group.

5. DISCUSSION

The low optimal take-off angle identified for successful dives has a direct coaching implication: technique cues emphasising a flat, driving dive trajectory -- rather than an upward leaping motion -- are likely to be mechanically favourable for gaining evasive distance, echoing standard advice in other diving and diving-evasion contexts across sports. The clear advantage of sequential landing over stiff-armed landing reinforces a safety-relevant coaching priority,

since stiff-armed landings concentrate impact force over a shorter time window in a manner comparable to the elevated joint loading associated with poor landing sequencing documented in other rapid-movement research (Colby et al., 2000). The seated-blocking results indicate that stability and reactive speed are not simply proportional; a moderately wide, pre-flexed posture outperformed both a narrow, upright posture and, by extension, would be expected to outperform an excessively wide, over-extended one, suggesting an optimal rather than maximal base of support for this role. This nuance is consistent with the broader agility literature's treatment of readiness posture as a coordinated, trainable skill rather than a passive default position (Verstegen & Marcello, 2001).

The findings suggest that kho-kho's core skills -- sprint-chase, evasive cutting, the kho exchange and pole turn, and diving/blocking -- share recurring mechanical themes: a consistent preference for a lowered, pre-loaded COM before explosive action, and a repeated trade-off between force magnitude and the time over which it is applied or absorbed. As with the preceding papers, the present sample size, the use of simulated rather than fully competitive match conditions, and reliance on two-dimensional video for a subset of joint-angle measures limit precision; three-dimensional motion capture and a larger, mixed-sex, multi-level sample would strengthen future replications of this work.

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