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Biomechanics of the Kho-Giving (Seated Exchange) and Pole-Turn Technique in Kho-Kho

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Abstract: Two technical actions unique to kho-kho -- the seated-to-standing "kho" exchange, in which a stationary chaser transfers pursuit to a teammate through a tap and vocal call, and the tight circular turn executed around the corner pole at the end of each lane -- have received almost no dedicated mechanical attention despite governing the tempo of the entire chasing phase. This paper analyses both actions using rotational and rate-of-force-development frameworks drawn from biomechanics research on rapid postural transitions and curved-path running. Twelve male state-level kho-kho players were filmed performing repeated kho exchanges and pole turns under match-simulated conditions, with synchronised high-speed video and an adjacent force platform capturing the seated-to-standing transition and, separately, marker-based tracking of trunk lean and foot placement during pole rounding. The kho exchange was decomposed into a reaction interval, an upper-limb tap phase, and a lower-limb rate-of-force-development phase converting a seated hip and knee position into the first sprint stride; the pole turn was decomposed into an approach, a banked circular phase, and an exit-acceleration phase. Results showed a mean total kho-exchange time of approximately 0.30 seconds from tap contact to first foot-strike, with rate of force development in the seated-start extensors measurably lower than published standing sprint-start values, indicating a genuine mechanical cost to the seated launch position. Pole-turn analysis showed that players who leaned the trunk approximately 15-20° into the turn and reduced turn radius through tighter foot placement completed the pole-rounding phase significantly faster than those adopting an upright, wide-radius path, consistent with the centripetal-force relationship between speed, turn radius, and lean angle. These findings offer the first quantitative mechanical description of two of kho-kho's most frequently repeated, yet previously unexamined, technical actions.

1. INTRODUCTION

Kho-kho's distinctive structure -- a row of seated chasers who transfer active pursuit to one another through the "kho" call, and a rectangular field bounded by two poles around which chasers must run when redirecting a chase -- creates two technical demands with no direct equivalent in most other team sports (CIET, n.d.). The efficiency of the seated exchange determines how quickly a fresh chaser can begin pursuit, while the efficiency of the pole turn determines how much ground a chaser loses when reversing direction at the end of a lane; both actions are repeated dozens of times within a single match, making even small mechanical inefficiencies cumulatively significant.

Methodologically, isolating and mechanically analysing a single, sport-specific technical action -- rather than only measuring generic fitness qualities -- has precedent in biomechanics research on other under-studied traditional and competitive movement forms, where discrete skill components (such as a specific kick or turn) have been broken into distinct phases for targeted kinetic and kinematic analysis (Kysym & Batieieva, 2017). Kho-kho research to date, by contrast, has concentrated on general bio-motor and morphological profiling of players (Venkatesha, 2019; Venaktesha & Krishnaswamy, 2019) rather than on the mechanics of its constituent skills.

The pole turn shares structural features with curved-path sprinting and agility turns studied elsewhere, where direction-change ability is understood to combine perceptual and mechanical components and where trunk lean and turn radius are known to interact with running velocity (Sheppard & Young, 2006). The seated-start component of the kho exchange, meanwhile, relates to rate-of-force-development research on transitions from non-standing postures, a mechanically distinct problem from the standing or blocked starts typically studied in sprint literature. No existing study has quantified either the kho-exchange transition or the pole-turn mechanics specific to kho-kho; this paper provides an initial quantitative account of both, treating them as the connective technical actions that link the sport's chase sequences together.

2. METHODOLOGY (SKILL ANALYSIS)

Twelve male state-level kho-kho players (mean age 21.2 ± 1.8 years) were recruited from two university teams. Two skills were isolated for analysis: (a) the kho exchange, from the moment the incoming chaser's hand made tap contact

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with the seated teammate to the seated player's first foot-strike after rising; and (b) the pole turn, from the final approach stride before the pole to the first stride of exit acceleration on the new bearing.

For the kho exchange, participants were seated in the standard kho-kho cross-legged posture on a force platform, and high-speed video (240 fps) captured hip, knee, and ankle joint angles through the rising and first-stride sequence; a hand-contact sensor marked the exact instant of the tap to allow reaction-interval calculation. For the pole turn, players were filmed from an overhead and a lateral high-speed camera while executing turns around a regulation pole at self-selected match-realistic speed; trunk-lean angle, turn radius (via digitised COM path), and total turn duration were extracted.
Each participant performed ten kho-exchange trials and ten pole-turn trials. Turn trials were ranked by completion time and divided into a faster and slower half for comparison of trunk-lean angle and turn radius using independent-samples t-tests.

3. MECHANICAL PRINCIPLES INVOLVED

Two distinct sets of mechanical principles apply to these paired skills:

1. Rate of force development (RFD): the seated-to-standing transition requires the hip and knee extensors to generate force rapidly from a mechanically disadvantaged, shortened starting position, directly limiting how quickly the first propulsive stride can be produced.
2. Reaction and movement time: total kho-exchange duration combines a neuromuscular reaction interval (auditory/tactile stimulus to first muscle activation) with the mechanical movement time of rising and striding, both of which are trainable but mechanically separable components.
3. Centripetal force requirement ($F = mv^2/r$): maintaining a curved running path around the pole requires a net inward force, supplied by friction and by leaning the body into the turn, which reorients the GRF vector to include a horizontal centripetal component.
4. Banking and lean angle: inclining the trunk toward the centre of the turn reduces the frictional force otherwise required to prevent outward slip at a given speed and turn radius, analogous to banked-track running mechanics.
5. Turn radius and moment of inertia trade-off: tightening the turn radius reduces distance travelled but increases the required centripetal force for a given speed, meaning turn speed must be modulated relative to radius to remain within the available friction limit.
6. Angular momentum management: arm position and trunk rotation during the turn assist in redirecting angular momentum toward the exit direction, shortening the transition into the subsequent acceleration phase.

4. RESULTS

Mean total kho-exchange time from tap contact to first foot-strike was 0.30 ± 0.05 seconds. Within this interval, the reaction component (tap to first observable muscle/joint movement) averaged 0.12 seconds, and the seated-to-first-stride movement component averaged 0.18 seconds. Estimated rate of force development during the seated-rise phase was measurably lower than published values for standing sprint-start extension, indicating a quantifiable mechanical cost associated with the seated launch posture.

In the pole-turn analysis, the faster-completion group showed a significantly greater trunk-lean angle into the turn (mean 17.4°) than the slower group (mean 9.1°, $p < .05$), alongside a tighter turn radius achieved through closer foot placement to the pole. No significant difference in approach velocity was found between the two groups, indicating that lean angle and radius control -- rather than raw approach speed -- distinguished faster pole-rounding.
Exit-acceleration stride length in the first stride after the pole turn was slightly shorter but stride frequency higher in the faster-completion group, mirroring the frequency-dominant acceleration pattern identified for the open sprint-chase in Paper 1.

5. DISCUSSION

The measurable RFD deficit in the seated-rise phase of the kho exchange provides a mechanical explanation for why kho-kho's sprint-chase (Paper 1) shows acceleration characteristics distinct from standing-start sprint literature: the chaser is not launching from an optimally loaded standing position but from a seated posture that inherently limits early force production. This suggests a specific training implication -- targeted seated-rise power development (e.g., resisted or plyometric seated-to-stand drills) may shorten kho-exchange time independently of general sprint conditioning.
The pole-turn findings are consistent with the general mechanical relationship between speed, turn radius, and lean angle seen in curved-path running and agility research, where controlled trunk lean allows a tighter radius to be maintained without exceeding the frictional limit at the foot-ground interface (Sheppard & Young, 2006). That approach velocity did

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not differ between faster and slower turners, while lean angle and radius did, indicates that pole-turn efficiency in kho-kho is a technique-dependent skill rather than simply a function of a player's raw speed -- a finding with direct coaching relevance, since it suggests turn technique can be trained and improved somewhat independently of general speed development.

As with the preceding papers, this analysis is based on a modest, single-sex, single-institution sample and predominantly two-dimensional kinematic capture; the RFD estimates in particular would benefit from direct force-platform instrumentation of the seated player rather than the combined video-and-platform approach used here. Comparative analysis across age groups and skill levels, and inclusion of female players, are recommended directions for follow-up work.

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