LANDING STRATEGY MODULATION IN BACKWARD ROTATING PIKED AND TUCKED SOMERSAULT DISMOUNTS FROM BEAM

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The aim of this study was to develop understanding of the landing strategy modifications made when performing backward rotating piked (BP) and tucked (BT) dismounts from beam. Sagittal plane lower-body joint angular kinematic profiles were determined for four female gymnasts during the landing phase of BP and BT somersaulting dismounts. A common hip-biased landing strategy was employed by the four gymnasts in the dismounting skills. The more complex BP task was distinguished by the use of a more extended (3.7º) and flexed (5.0º) initial knee and hip joint configuration, respectively compared to the basic BT skill performed. Effective skill developments of backward rotating dismounts from beam may require modulation to the individual joint patterns defining the lower-body landing strategy.

KEY WORDS: strategy bias, lower-body control, kinematics, gymnastics

INTRODUCTION: The dismount is a critical element of a gymnastic routine. Complex dismounts evolve from gymnasts acquiring the more basic tucked version prior to the integration of more complex versions, which are distinguished by diverse spatial orientation objectives. In dismounts from the beam apparatus, an aerial phase comprising forward or backward rotating somersaults with or without twists about the longitudinal axis may be performed. Although, the backward tucked somersault may be considered a basic skill for competitive gymnasts to perform, the spatial and temporal constraints of the skill are complex (Davlin *et al.*, 2001).

The entire dismount can be defined by separate aerial and landing phases, where the onset of each is established by the loss of contact with the apparatus and first contact with the landing surface, respectively (Gervais & Dunn, 2003). The mastering of a pre-programmed movement pattern in the landing phase of the 'simplistic' backward tucked (BT) dismount has been considered important in minimising point deductions and maximising safety in landing (Gervais & Dunn, 2003). Contacting the ground with an appropriate kinematic pattern i.e. body position and angular velocity, ensures a gymnast can achieve landing balance during dismounting (Sheets & Hubbard, 2007). While studies of simple drop landings have reported relatively invariant kinematic control strategies (McNitt-Gray, 1991), more complex gymnastic landings distinguished by diverse initial momentum conditions have been suggested to require a control strategy that uses a hierarchical relationship between more than one criteria (McNitt-Gray *et al.*, 2001). The execution of a modified landing strategy capable of accommodating the requirements of more complex dismount skills from beam e.g. the backward piked (BP) version may subsequently be necessary to ensure skill-specific mastery and the achievement of a successful and 'safe' landing.
A mechanical understanding of control strategies used in basic and more complex skills has been advocated to be valuable in providing a mechanism for effective skill development (Irwin & Kerwin, 2007), enhancing performance, and minimising potential injury risk in landing. The aim of this study was to develop understanding of the kinematic strategy used in the landing phase of backward rotating dismounts from beam. The diverse spatial orientation objectives of the BP and BT skills were hypothesised to impose modulations in the lower-body joint kinematic strategies used in the landing phase.

METHODS: Four national level female gymnasts (mean ± SD height: 1.64 ±0.08 m, body mass: 59.0 ±6.9 kg) provided written informed consent to participate in the data collection, for which the protocol had been approved by the University's Research Ethics Committee. Each gymnast performed 10 successful backward single somersault dismounts from beam in a piked and tucked position (N = 80 trials). Successful performances were qualitatively judged by a national-level coach using the FIG Code of Points (2008).

Active markers were located on the lateral, right side of each gymnast at the metatarsalphalangeal (mtp) and on the ankle, knee, hip and shoulder joint centres. Co-aligned CODA CX1 motion analysis scanners (Charnwood Dynamics Ltd., Leicestershire, UK) were used to obtain marker locations (sample rate: 200 Hz; sample duration: 6 s) during each dismount routine. The three-dimensional coordinate data of each marker were reduced to two-dimensions (z-vertical and y-anterior-posterior) and low-passed filtered at 10 Hz.
The onset of the dismount phase was established as the instant at which the mtp z-displacement first exceeded the respective loaded displacement on the beam. The landing phase was defined as the duration between first ground contact, established by the descent of the vertical displacement of the mtp marker below the unloaded landing surface height and the instant at which the mtp joint maintained a stable, loaded position on the ground.
Ankle, knee and hip joint flexion-extension angular displacements and velocities were determined for each landing phase. Strategy bias, which was used by McNitt-Gray *et al.* (1994) to define drop landing strategies, was determined as the ratio of the knee-hip minimum in the joint angle profile of the landing phase. Skill- and phase-specific initial joint angle configurations, range of motion (ROM) and peak angular velocities, which were determined as the mean across all respective trials (BP: 40 trials; BT: 40 trials), were also used to describe the skill-specific landing strategy. Paired t-tests (15 tests) were performed to analyse between skill differences (n = 40 trials for each skill) in the phase duration, strategy bias, and each joints initial configuration, ROM and magnitude and time of peak angular velocity. The statistical significance level was set at $p<0.05$ for all analyses.

RESULTS: The BP landing phase duration (mean ±SD: 0.48 ±0.10 s) was significantly shorter than ($p<0.05$) the more basic BT skill (mean ±SD: 0.51 ±0.11 s). When expressed relative to the dismount duration, landing phase durations were similar between skills. Strategy bias measures consistently exceeding one indicated the use of a similar hip-biased strategy in the BP (mean ±SD: 1.56 ±0.26) and BT (mean ±SD: 1.57 ±0.35) landing phases.

As illustrated in Table 1, the strategies were differentiated ($p<0.05$) by the use of a 3.7º more extended and 5.0º more flexed initial knee and hip joint configuration, respectively in the BP compared to the BT skill. While similar knee and hip joint flexion ranges were employed, a significantly larger ($p<0.05$) ankle joint ROM and more rapid hip joint angular velocity were used across the landing phase of the BP compared to the BT skill. No significant difference between skills was found in the timing of the peak joint angular velocities.

Table 1 Mean [SD] landing phase kinematics for BP and BT somersault dismounts

	Initial Ankle θ (°)	**Initial Knee θ (°)***	**Initial Hip θ (°)***
BP	107.7 [9.3]	160.0 [4.9]	100.8 [7.6]
BT	106.4 [10.4]	156.3 [5.8]	105.8 [8.1]
	ROM Ankle θ (°)*	**ROM Knee θ (°)**	**ROM Hip θ (°)**
BP	34.1 [7.3]	60.2 [9.2]	43.2 [16.3]
BT	32.0 [7.3]	62.8 [9.8]	48.8 [4.6]
	Peak Ankle ω ($rad.s^{-1}$)	**Peak Knee ω ($rad.s^{-1}$)**	**Peak Hip ω ($rad.s^{-1}$)***
BP	-8.7 [2.1]	-11.5 [0.9]	-6.4 [1.1]
BT	-7.8 [2.3]	-11.5 [1.1]	-7.4 [2.3]
	Time of Peak Ankle ω (% phase)	**Time of Peak Knee ω (% phase)**	**Time of Peak Hip ω (% phase)**
BP	1.7 [2.4]	10.8 [2.6]	17.8 [3.9]
BT	2.2 [2.3]	11.1 [2.9]	16.9 [3.3]

*Significant difference between skills at p<0.05

The knee joint was associated with the largest joint angle changes across the landing phase profile compared to the ankle and hip joints. When expressed as a percentage in the BP joint angle range, the root mean squared difference (RMSD) between the landing phase joint angle-time profiles of the skills was 3.8 %, 8.8 %, and 6.4 % for the ankle, knee and hip joints (Figure 1a), respectively. As illustrated in Figure 1b, the knee joint contrastingly produced the most invariant joint angular velocity profile between skills (RMSD: 1.9 %), when compared to the ankle (RMSD: 5.4 %) and hip motions (RMSD: 3.7 %).

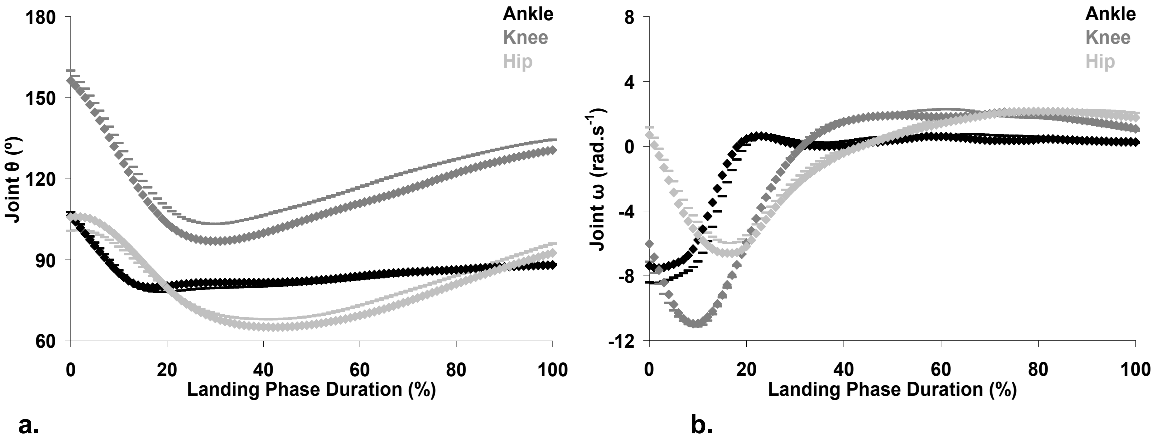

Figure 1: Group ensemble landing phase (a) joint angle [θ] and (b) angular velocity [ω] time profiles during the BP (thin) and BT (thick) dismount skills.

DISCUSSION: The aim of this investigation was to develop insight into the kinematic landing strategy modifications made when performing backward rotating piked and tucked dismounts from beam. Although the BP and BT skills are differentiated in complexity by diverse spatial orientation objectives in the aerial phase, a common hip-biased landing strategy was employed in the basic (BT) and more complex (BP) skill. The use of a hip-biased landing strategy has previously been suggested for gymnasts performing simplistic controlled drop landing task (McNitt-Gray, *et al.,* 1994). The marginally shorter landing phase duration of the BP compared to the BT skill demonstrated that the more complex skill may have incurred slightly increased whole body momentum reduction demands on the gymnasts compared to the basic skill.

While a common global lower-body strategy was employed between skills, modulations in the local control strategy i.e. individual joint movement responses were made to accommodate the more challenging mechanical demands incurred with the more complex dismount skill. The BP landing strategy was characterised by individual joint movement patterns comprising a more extended knee at initial ground contact and simultaneously a more flexed hip than used in the BT skill. Discrepancies in the spatial orientation of the hip during the aerial phase of each skill may explain an earlier occurring, and more pronounced hip joint flexion in the BP compared to the BT landing phase, which was compensated for by a comparatively more extended knee joint at the onset of landing. The use of a relatively more rapid hip joint motion and greater ankle joint ROM during the subsequent ground contact phase of the BP skill may be a further compensatory response to the constrained contribution to whole body momentum reduction provided by the hip at the onset of landing. The more extended (3.7º) and flexed (5.0º) respective initial knee and hip joint configurations used in the BP compared to the BT skill suggested that lower-body and joint-specific strategy modulations may be achieved with increasing skill complexity. The diversity in the joint kinematic patterns used in the BP and BT skills investigated subsequently confirmed the study's hypothesis and supported previous suggestions that multi-joint control in landing tasks should consider local mechanical objectives (McNitt-Gray *et al.*, 2001) and modified strategies may be required in more complex gymnastic dismounts (McNitt-Gray *et al.*, 1994).

Between-skill comparisons in joint configuration profiles suggested that the increased dismount complexity was associated with greater modulations in the knee and hip joint configurations across the entire landing phase compared to the ankle joint. More successful landing performances in BT somersaults have previously been characterised by greater knee and hip joint excursions (Gervais & Dunn, 2003). The similarity in knee (BP: 60.2º; BT: 62.8º) and hip joint (BP: 43.2º; BT: 48.8º) ROM in the BP and BT landing strategies may however suggest that increasing dismount complexity does not compromise landing performance for the four gymnasts investigated. The association between the level of success of the landing performance and the associated joint kinematics was however not considered in this investigation. Future examination of successful and unsuccessful backward rotation dismounts using a larger sample size of gymnasts may therefore be warranted to gain further insight the landing performance constraints incurred by increasing skill complexity.

CONCLUSION: Whilst a common lower-body multi-joint control strategy was used in the skill development of backward rotating dismounts from beam, the landing objectives of a more complex dismount task was achieved through modulation of independent joint movement patterns. The development from a basic tucked to more complex piked dismount skill may be suggested to require a joint-specific modulation in the configuration at the onset of landing and across the landing phase profile.

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