VARIATION IN LANDING DURING GYMNASTICS SKILLS

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The aim of this study was to examine joint motion during landing from a variety of gymnastics skills. Twelve gymnasts performed a range of gymnastics skills with a landing component. Joint angles of the ankle, knee and hip were examined during landing from five different skills. There were significant differences between skills at all joints for peak flexion and extension (ankle, knee and hip: $p<0.001$), as well as range of motion (ankle: $p<0.001$; knee: $p<0.05$; hip: $p<0.001$). These differences are attributed mostly to the constraints of the preceding skills and may affect the risks of injury during landing. These results suggest that studies of strategies during landing from drops and simple jumps may have to be carefully considered before they can be applied to gymnastics landings.

KEY WORDS: gymnastics, landing, kinematics.

INTRODUCTION:

Landing from a period of flight imposes an impact on the musculoskeletal system which must be controlled by the structures involved in landing. During many landings in gymnastics the intention is to bring the body to rest; flexion of the ankle, knee and hip joints assist in attenuating the force of these impacts (DeVita & Skelly, 1992; Lockwood, Baudin, & Gervais, 1995). Strategies employing large lower extremity flexion are most likely to reduce the magnitude of the peak ground reaction forces (Lees, 1981; McNitt-Gray, 1989).
Analyses of strategies used when landing from simple drops are available (Lees, 1981; McNitt-Gray, 1989; Seegmiller & McCaw, 2003) but during gymnastics performance landing strategies are constrained by the requirements of different skills. This study aimed to compare sagittal plane kinematics during landing on the feet from several gymnastics skills.

METHOD:

Data Collection: Twelve female gymnasts were recruited from gymnastics clubs in the Sydney Metropolitan Area. Participants were aged between 11 and 20 years and were competing between levels five and ten in the Australian levels program.
Each gymnast completed a warm up and practiced the skills to be tested. Markers were placed on the right side of the body at the following landmarks: the head of the fifth metatarsal, the lateral malleolus, the lateral femoral condyle, the anterior superior iliac spine, and the sacrum. Gymnasts then performed selected gymnastics skills that involved a foot landing phase. The skills examined were limited to those where joint movements during landing occurred primarily in the sagittal plane: the straight jump; tuck jump; round-off; back flip; and the tuck back salto. Skills were performed on a 10 cm thick foam landing mat typically found in gymnastics training centres.
2D video data were sampled at 500Hz. The Phantom camera was perpendicular to the sagittal plane of movement, four metres from the gymnast and one metre from the ground.

Data Analysis: The landing phase was analysed from touchdown (TD), the first point of contact of the foot with the ground to 0.2 seconds after touchdown. The literature (Fritz & Peikenkamp, 2001; Lees, 1981; Nigg, 1989) shows that impact absorption is achieved during this period. Data were filtered using a low pass Butterworth filter with a cut-off frequency of 50 Hz. 2D kinematics were calculated, from marker position data obtained from video using a model written in Matlab®. Joint angles were calculated as the global angle of the distal segment relative to the global angle of the adjoining proximal segment. Peak values for flexion and extension as well as joint range of motion (ROM) during landing were determined.

Data for each participant were averaged for each skill to obtain representative data for each subject before averaging across participants. Significant differences in overall results between skills were determined using up to three trials for each subject, for each skill. A one-way within-subjects analysis of variance (ANOVA) with replication and type IV sum of squares, was performed in SPSS®.

RESULTS:

The lower body kinematics during landing of five skills and a total of 130 trials were analysed. During ANOVA tests the gymnast and skill terms were found to be significant in the statistical model and the interaction between these terms was also significant. The trial term was found to be not significant showing that there was no effect of the trial number on the results.
The kinematics of several trials were unable to be analysed as markers were out of view for a long period of time. This occurred particularly during the back saltos as the arms holding the shank obscured both the greater trochanter and knee markers. Table 1 summarises the local angles at the joints at the point of touchdown and the ROM during the landing phase.

Table 1. Joint position at touchdown and ROM during landing (deg) (mean ± 1SD)

	Joint postion at touchdown			Joint ROM during landing		
Skill	Ankle	Knee	Hip	Ankle	Knee	Hip
straight jump	-38 ± 19	-38 ± 19	9 ± 18	11 ± 14	9 ± 18	11 ± 14
tuck jump	-4 ± 12	-4 ± 12	112 ± 15	71 ± 10	112 ± 15	71 ± 10
round-off	25 ± 20	25 ± 20	49 ± 21	28 ± 19	49 ± 21	28 ± 19
back flip	3 ± 24	3 ± 24	-1 ± 5	49 ± 19	-1 ± 5	49 ± 19
back salto	36 ± 11	36 ± 11	34 ± 28	77 ± 19	34 ± 28	77 ± 19

Variations were seen in patterns of kinematics during landing from different skills. The mean (± SD) for time series data of sagittal kinematics is presented in Figure 1; from two seconds prior to TD to two seconds after TD. The vertical line represents the time of TD. Round-off kinematics are shown post-TD only, as the segments were out of plane prior to this point.
All skills except the back salto show dorsi flexion after TD; during the back salto the ankle is already in a large amount of dorsi flexion at TD. The straight jump, back flip and back salto show an increase in knee flexion after TD. However the tuck jump, round off and front salto show only relatively minor changes, as the knee was already in some degree of flexion at TD. Hip flexion follows a general trend during most skills except the straight jump where the hip was in full extension at TD. During the straight jump there is continuing hip flexion; in other skills there is an initial extension prior to flexion.
Ankle and knee joints showed in general greater range of motion (ROM) than the hip as well as greater variation between skills. Significant differences in joint ROM during landing were found for the ankle and knee (ANOVA ankle: $p < 0.001$; knee: $p < 0.05$) as well as for the hip joint (ANOVA $p < 0.001$). Maximum flexion and extension varied between skills at the ankle ($p < 0.001$ for both plantar and dorsi flexion), knee ($p < 0.001$ for both flexion and extension) and hip ($p < 0.001$ for both flexion and extension) using univariate ANOVA with replication.
There were significant but very weak relationships between joint range of motion and vertical velocity at touchdown (Ankle ROM: $r = -0.28$, $p <0.01$; Knee ROM: $r = -0.33$, $p<0.001$; Hip ROM: $r = 0.23$, $p < 0.01$).

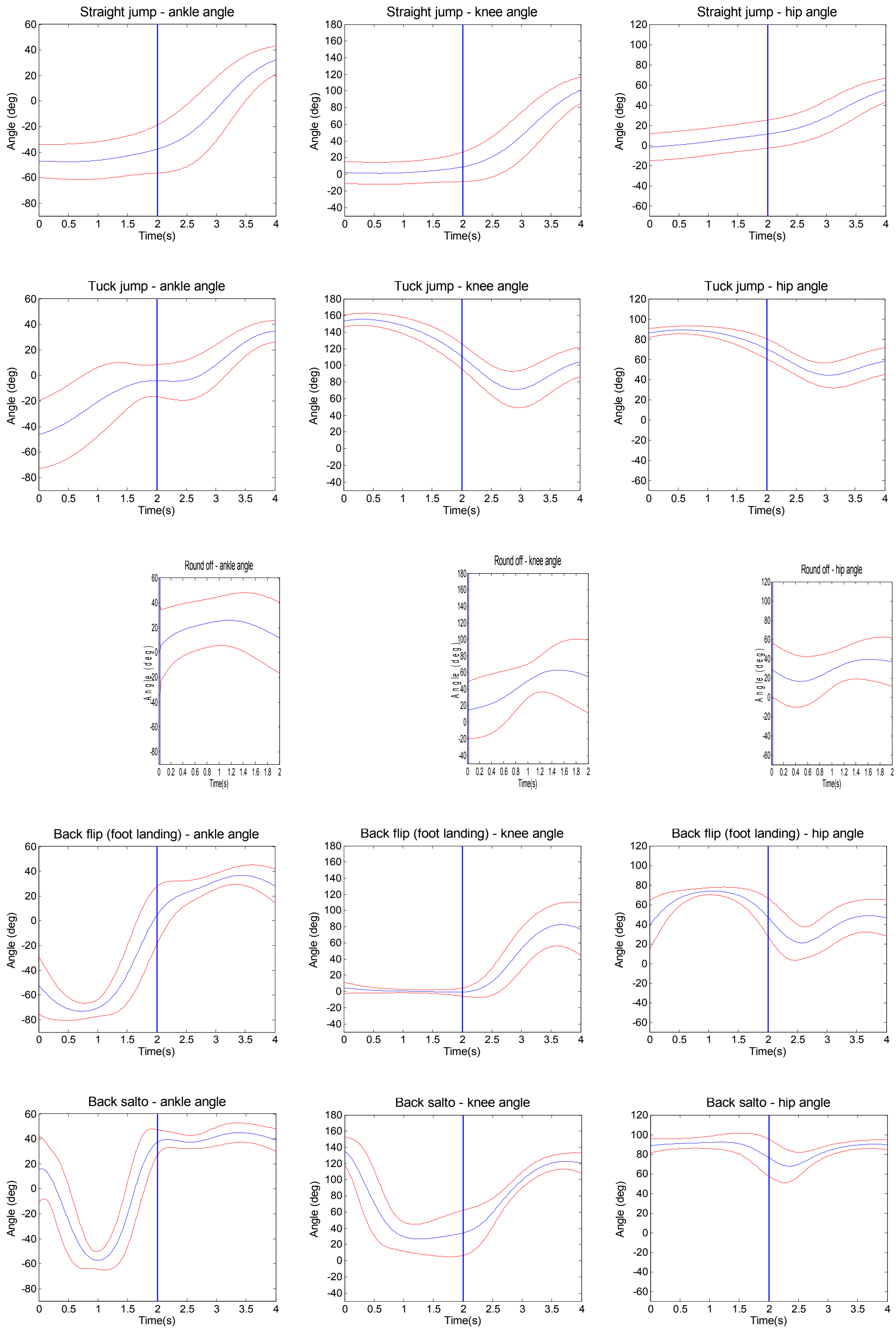

Figure 1. Kinematics of lower body joints during landing from gymnastics skills

——— mean angular displacement ——— mean plus and minus one standard deviation

DISCUSSION:

Time series data of joint angular displacement show differing patterns of sagittal plane motion during different skills and the joint angle at touchdown also varies greatly as seen in Table 1Table . This variability could be due to the range of skill levels of gymnasts participating in this study or may be more inherent in the performance of the skills. It is suggested that most of these differences can be attributed to the position of segments at touchdown relative to one another and to the direction of the ground reaction force vector.
There was no strength in the relationship between joint range of motion and the vertical velocity at touchdown. Consequentially, the ability of the joints to contribute to absorption of landing energy may be compromised. If joints are already in a largely flexed posture at touchdown, the range of motion available during the rest of the landing phase is limited. As joints are flexed to absorb energy during landing and to maintain balance (DeVita & Skelly, 1992; Lockwood, Baudin, & Gervais, 1995), if the range of motion is limited then joints may be also limited in their ability to contribute to energy control during the impact.
The ability of the performer to apply a landing strategy is important for the risk of injury in gymnastics – both acute and chronic. If forces are not transferred through the body in a manner in which the musculoskeletal system can suitably manage and tolerate, then structures may be unadapted to the magnitudes involved, and the possibility of acute injury is immediate and accumulated damage ongoing.

CONCLUSION:

Many studies have examined isolated landing involving vertical displacement from different drop heights and onto different matting (DeVita & Skelly, 1992; McNitt-Gray, 1989; Seegmiller & McCaw, 2003; Zhang, Bates, & Dufek, 2000). There is considerable variation found between and within skills for kinematics of landing as seen from the results of this study. This may make examinations of simple drop landings described in the literature, from different heights and onto different surfaces, less directly related to landing strategies used by gymnasts during training or competition than at first thought. These analyses of landing strategies after vertical jumps and drops may not be transferable to the landing of more demanding skills due to the complications of preceding kinematics.

REFERENCES:

Lees, A. (1981) Methods of impact absorption when landing from a jump. *Engineering in Medicine*, 10(4): p. 207-211.

Lockwood, K.L., Baudin, J.P., and Gervais, P.L. (1995) Kinematic characteristics of impact absorption during landings of multi-revolution jumps in figure skating. in *XIII International Symposium on Biomechanics in Sports*. *Lakehead University, Thunder Bay, Ontario, Canada.*

McNitt-Gray, J.L. (1989) The influence of impact speed on joint kinematics and impulse characteristics of drop landings. in *XII International Congress of Biomechanics*. *University of California, Los Angeles, Los Angeles, California, USA.*

Nigg, B.M., (1989) The validity and relevance of tests used for the assessment of sports surfaces. *Medicine and Science in Sports and Exercise*, 22(1): p. 131-139.

Seegmiller, J.G. and McCaw, S.T. (2003) Ground reaction forces among gymnasts and recreational athletes in drop landings. *Journal of Athletic Training*, 38(4): p. 311-314.

Decker, M.J., et al. (2003) Gender differences in lower extremity kinematics, kinetics and energy absorption during landing. *Clinical Biomechanics*, 18(7): p. 662-667.

Zhang, S.-N., Bates, B.T. and Dufek, J.S. (2000) Contributions of lower extremity joints to energy dissipation during landings. *Medicine and Science in Sport and Exercise*, 32(4): p. 812-819.