LANDING STRATEGY VARIATIONS: EFFECTS OF SKILL LEVEL, TASK DEMANDS AND MOVEMENT TYPE

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INTRODUCTION: The loading of various body structures during landing has been implicated as a source of injury in many sports activities, with injury prevention the focus of most contemporary sport related landing research (Hopper et al., 1995; Dufek & Bates, 1991). Subjects have typically been tested under isolated experimental conditions while performing the movement task of landing and remaining in a stable position. Though this movement modality may provide for a large degree of experimental control, such studies of discrete, endpoint landings may not account for all biomechanical aspects of landings performed in conduction with other movements; a situation which is present in cases where high rates of injury have been reported (Dufek & Bates, 1991). The purpose of the present study was therefore to evaluate selected aspects of lower extremity function during discrete landings and during landings preparatory to a subsequent movement activity, represented by a drop jump.

METHODS: Eight female subjects volunteered to participate in this study. Four subjects represented a group of skilled athletes having recently completed an off season plyometric training program including the landing and drop jump movement. The remaining four subjects represented a group of recreationally active females not currently engaged in any extensive athletic or fitness training program. Discrete landings were performed from a raised platform and culminated in a stable position on the landing surface. The preparatory landings comprised the initial landing phase of a drop jump movement executed from the same initial position as the discrete landing, but requiring subjects to perform a maximum effort vertical jump after dropping onto the landing surface.

After reading and signing forms of informed consent, each subject performed discrete landing and drop jump trials from each of four heights (16, 32, 48 and 64 cm). A block of five discrete landings was followed by a block of five drop jump trials at each height, with height conditions presented in order from least to most demanding. Ground reaction force (GRF) and kinematic data were collected for each trial, using an AMTI dual force platform system (1000 Hz) and a Motion Analysis Corporation passive reflector based autodigitizing system (200 Hz), respectively. Data reduction produced 11 GRF and 18 kinematic variables for each trial. Calculations of joint stiffness (Vieten & Larkins, 1993) produced five additional variables. Of the 34 total variables describing each trial, 20 represented impact phase parameters and 14 represented post impact phase parameters (Table 1).

A three-way repeated measures ANOVA was conducted for each variable using the mean of the five trials performed by each subject at respective height and movement conditions. The three factors present in the statistical design were defined as Skill Level, Movement and Height, with Skill Level and Movement factors consisting of two levels each and Height consisting of four levels. Significant main effects of Skill Level and Movement factors were evaluated directly relative to differences between the two treatment means for each factor. For significant interaction effects of Skill Level and Height, Movement and Height and Skill Level and Movement, simple effects of one factor were evaluated at each level of the remaining factor.

RESULTS AND DISCUSSION: ANOVA results are presented relative to each factor and variable in Table 2. An examination of the Skill Level factor main and simple effects indicated that the recreation group took longer to reach forefoot impact (75% greater T1), employed greater knee range of motion (17% greater KnROM), and achieved a lower stiffness magnitude by the time of F3 (21% lower StF3). This group generated more vertical impulse by the time of F3 (21% greater IF3), but this was accomplished over a longer time period (26% longer T3). The skilled group maintained greater stiffness levels during both the impact

Table 1. Variable Definitions

Vertical Ground Reaction Force			
F1	Magnitude of forefoot impact	F2	Magnitude of rearfoot impact
F3	Magnitude of post impact loading force	IF2	Cumulative impulse from contact to F2
IF3	Cumulative impulse from contact to F3		
Knee and Hip Joint Angular Displacement and Velocity			
KnCon	Knee joint angle at contact	KnMax	Maximum knee joint angle
KnROM	Knee range of motion during landing	KnF1	Knee angle at time of F1
KnF2	Knee angle at time of F2	KnF3	Knee angle at time of F3
KnVMax	Maximum knee angular velocity	HpCon	Hip joint angle at contact
HpMax	Maximum hip joint angle	HpROM	Hip range of motion during landing
HpF1	Hip angle at time of F1	HpF2	Hip angle at time of F2
HpF3	Hip angle at time of F3	HpVMax	Maximum hip angular velocity
HpCon	Hip joint angle at contact		
HpMax	Maximum hip joint angle	HpROM	Hip range of motion during landing
HpF1	Hip angle at time of F1	HpF2	Hip angle at time of F2
HpF3	Hip angle at time of F3	HpVMax	Maximum hip angular velocity
Lower Extremity Stiffness			
St1	Average stiffness during rearfoot impact phase		
St2	Average stiffness from end of rearfoot impact phase to time of KnMax		
StMax	Magnitude of maximum lower extremity stiffness		
StF3	Magnitude of lower extremity stiffness at time of F3		
Absolute and Relative Temporal Variables			
T1	Time of F1	T2	Time of F2
T3	Time of F3	TKnMax	Time of KnMax
TKnVMax	Time of KnVMax	THpMax	Time of HpMax
THpVMax	Time of HpVMax	TStMax	Time of StMax
T1-rel	T1 represented as a proportion of time to maximum knee flexion		
T2-rel	T2 represented as a proportion of time to maximum knee flexion		
T3-rel	T3 represented as a proportion of time to maximum knee flexion		

and post impact phases, although the group differences diminished as height increased. Skill Level differences were also apparent for impact phase time and impulse variables, which diminished as height increased as well. Relative to the Movement factor, the observation of 11 significant main effects encompassing variables from all categories suggests a general change in movement pattern when moving from the discrete landing to the drop jump task. The impact phase of the drop jump condition showed a greater degree of lower extremity flexion, lesser maximum knee joint angular velocity, and softer rearfoot impact that the discrete landing. During the post impact phase, the drop jumps resulted in a greater

stiffness and earlier occurrences of maximum flexion angles. Kinematic variable simple effects
supported the movement pattern differences identified by the Movement factor main effects. Greater knee joint flexion was associated with the discrete landing condition, with movement differences becoming more pronounced as height increased. Examination of Movement factor interactions with Height indicated that increases in landing demands did not effect a change in Movement differences relative to impact phase kinematics, but did effect an increase in Movement differences relative to post

Table 2. ANOVA Results

	Main Effects			Interaction Effects			
Variable	A	B	C	AxB	AxC	BxC	AxBxC
F1			**				
F2		*	**				
F3		**					
IF2	**		**		**		
IF3	*	**	**				
KnCon			**				
KnMax		*	*			**	
KnROM	*	*	**			**	
KnF1							
KnF2		**					
KnF3			**		*	**	
KnVMax		**	**				
HpCon		**	**			*	
HpMax			**			**	
HpROM		*	**			**	
HpF1		*	*				
HpF2		*					
HpF3		**	**		**	**	
HpVMax			**				
St1	**	**		*	**	**	
St2	*	*	**		*		
StMax	**	**		**		**	
StF3	**		**				
T1	*						
T2	*	**			**	**	
	Main Effects			Interaction Effects			
T3	*	**	*			*	
TKnMax		**	**				
TKnVMax							*
THpMax		**	**				
THpVMax			*				
TStMax	**	*	*		**		
T1-rel		**				**	
T2-rel		**	**		**	*	
T3-rel		**				*	
Total #	34	34	34	34	34	34	34
# Significant	11	23	23	2	8	14	1
Percent	32%	68%	68%	6%	24%	41%	3%

* p < 0.05   Factor Levels: A Skilled, Recreational
** P < 0.01   B Discrete Landing, Drop Jump
C 16, 32, 48, 64 cm

impact phase kinematics. An important transition point in movement pattern changes may lie near the 32 cm height, since non-significant or opposite differences were observed among the lower heights for post impact phase variables and no significant differences were observed at this point for impact phase variables.

CONCLUSIONS: Discrete landing research has typically focused on the impact phase, examining kinematics and kinetics no further than heel impact force (Caster & Bates, 1995), or perhaps the point at which the GRF slope evens out approximately 100 ms after touchdown (Schot et al., 1994). An important contribution of the present study included the evaluation of the complete landing phase. Significant effects for all factors were present to a greater degree relative to post impact phase variables. Relative to the Movement factor, representing the primary focus of this research, 93% of all post impact phase variables produced significant main or interaction effects, compared to 60% of the impact phase variables. Half of the post impact phase variables exhibited significant Skill Level effects, while no kinematic variables produced significant effects during the impact phase. Critical results relative to Skill Level and Movement factors could not have been identified had the analyses not proceeded temporally beyond the impact phase. The differences observed between discrete landing and drop jump movement tasks may be viewed generally as the influence of a post landing movement task on landing performance. Evidence of such jump driven control on the preparatory landing was found both in the present study and in the literature. Mechanically, the body must decelerate to zero velocity during the landing phase for both discrete and preparatory landings. Accomplishing more of this during the post impact period region may be beneficial to drop jump performance and represent a form of jump driven control. Bobbert et al. (1986) suggested that observed drop jump style differences reflect arbitrary subject choices. Greater knee flexion and range of motion values observed for the recreational group in the present study, as well as Skill Level differences in post impact phase stiffness, suggest that such a style difference may also reflect physical limitations relative to the preparatory landing demands.

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