LANDING DEVELOPMENT: A FIRST LOOK AT YOUNG CHILDREN

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The purpose of this study was to examine sagittal and frontal views of children (n=14) aged 4-9 landing from a maximal effort vertical jump to begin a description of landing development. Video records (collected at 30 frames/sec) of the jump and landing were viewed frame by frame with Windows Movie Maker and analyzed with a simple scoring system validated to detect improper movements during landing. Findings indicated that this stop-landing task challenged balance as most landings included a step, straddled foot position, and a wide stance. Mechanisms for force absorption (knee and hip flexion) tended to occur more often in landings of older children, but incidences of knee valgus also increased with age. Further investigation may establish developmental expectations for landing and help coaches and physical educators correct potentially harmful patterns as children age and pursue more competitive sport.

KEY WORDS: landing evaluation, motor development, pedagogy, youth sport

INTRODUCTION: Anterior cruciate ligament (ACL) injury risk increases when landings include little knee flexion, knee valgus (i.e., outward tending of the tibia distal to the knee), and too much tibial rotation (e.g., Hewett et al., 2006). Physical training programs can improve upon these potentially harmful patterns. In a large (n=1435) randomized controlled trial an alternate warm-up routine (Prevent Injury and Enhance Performance (PEP)) appeared to decrease ACL injury risk for college-level women soccer players by improving neuromuscular control (Gilchrist et al., 2008). However, a critical aspect of injury prevention may be instruction in proper movement techniques and correction of poor movements, for a less select group such as recreational athletes. DiStefano et al., (2009) advocates this approach. In her recent work, intervention programs targeted to correct strength and flexibility imbalances and postural malalignment when landing appeared successful for 10-17 year-old recreational youth soccer players (n=173). ACL injury risk increases about age 11-12 in soccer, so landing technique instruction prior to this age may benefit more sport participants.

In formal physical education (PE) classes, most school-aged children receive instruction that promotes competence with many movements, such as jumping and force absorption during landings. Teachers use multiple tools, including established developmental progressions that delineate quality movements (e.g., Wickstrom, 1977), to provide appropriate movement feedback. However, there is no developmental progression for landings. The physical educator does not know what lower extremity positions to expect at each age, making developmentally appropriate landing instruction impossible. The intent of this study was to begin a description of landing skill development in children (ages 4 to 9) though examination of knee and foot positions and movements when landing from a maximal effort vertical jump (MVJ). Educators and youth sport coaches may use knowledge of expected landing qualities at varied developmental stages to positively influence landing skills in young participants. Perhaps facilitating neuromuscular habits associated with decreased injury risk will better prepare young sport participants for landings later challenged by their own physical growth.

METHODS: Participants: Parents associated with a small New England college were informed of the study to gather a volunteer sample of 14 healthy children without lower extremity musculoskeletal injuries or disabling conditions. Three similar-aged subgroups were created (i.e., 4-5 yrs (n=6), 6-7 yrs (n=5), 7-8 yrs (n=3)) to permit developmental observations. College approved consent/assent forms were signed by a parent and the child(ren) prior to data collection. For each child, a parent indicated activity level and youth sport participation.

Data Collection: Data were collected in two sessions in a gymnasium. Prior to subject arrival two digital video cameras (Panasonic PV-DV400; Panasonic PV-GS55) were leveled and positioned (1.13 m high; 2.31 m from target: 0.94 m high; 1.53 m from target) to view the frontal and sagittal planes, respectively, of a MVJ and stop-landing task. Participants wore shorts, a short-sleeved shirt, and sneakers for data collection. Each child completed 5 min of lower extremity static stretching and jogging or ball kicking to warm-up. A research assistant determined each child's height, weight, standing reach, and MVJ height estimate. To estimate MVJ height, participants jumped as high as possible, once, to touch the wall marked with height increments. Next, each participant moved to the filming area and practised jumping to a target (a balloon (0.64 m circumference) hung from a yardstick positioned parallel to the floor and clamped to an adjustable Vertec® (Sports Imports, Inc. Columbus, OH)). Participants started from a line 0.39 m behind the target and completed 3-5 practise trials. Verbal instructions indicated for them to jump as high as possible, touch the balloon with both hands, and land balanced facing the camera. Starting with the estimated MVJ height, the target height was adjusted during practise to challenge each child, but still allow him/her to touch the balloon with both hands. Target height was recorded as MVJ height. After the practise, five MVJs and landings were filmed from the frontal and sagittal views.
Data Reduction: Digital video recordings were transferred to Windows Movie Maker (v. 5.1, Microsoft Corporation, 2007) for single frame viewing at 30 frames/sec. Developmental characteristics (e.g., Gallahue & Ozmun, 2006) of sagittal view MVJ trials were examined for maturity to ascertain MVJ task difficulty and help explain potential landing differences, as jumping maturity influences landing ability (Ayalon et al., 1987). Frontal and sagittal view landing characteristics were described using portions of the Lower Extremity Scoring System (LESS) (Padua et al., 2004), a clinical movement analysis tool assessed for validity and reliability to detect improper movement patterns during jump-landing tasks (e.g., Distefano et al., 2009; Padua et al., 2007). Tables 3 and 4 list the landing qualities observed; timing of foot contact and subsequent balance, stance width, toe position, foot placement, and knee and hip positions and motions at initial contact (IC) and maximum knee flexion (MxKFx). Two researchers reviewed these qualities in multiple trials to ensure evaluation criteria consistency. One researcher analyzed all of the data. Trials were excluded if the subject did not touch the target. Analyses used a binary technique (evidence for or against the presence of each jumping and landing characteristic was simply tallied). Number of occurrences was expressed as a percent of the number of jumps and landings. Simple descriptive analysis techniques were purposely selected to mimic tools that coaches or physical educators might use in their professional settings.

RESULTS AND DISCUSSION: With age participants' height, weight, jump height, and seasons of youth sport participation increased (Table 1). Parent survey responses showed that 78.6% of the children were moderately active after school and over the weekends (i.e., spent *more free time* doing activities that *kept the heart rate elevated*, {e.g., tag, basketball, soccer, scooters, in-line skates, free-play, biking, organized youth sport} than time in activities that did not elevate the heart rate much {e.g., video games, television, board games, reading, arts and crafts}).

Sagittal jumping observations showed that all subjects consistently used forceful extension at the hips, knees, and ankles from a 2-foot take-off coupled with upward head tilt focusing the eyes on the target. These qualities reflect mature jumping (Gallahue & Ozmun, 2006). In addition, the oldest participants' jumping patterns indicated 60^o-90^o of knee flexion in preparation (93% of jumps), no exaggerated trunk lean, no leg tucking during flight, and simultaneous coordination of the arm swing (33% of jumps) (Table 2). Other preparatory and jumping motions varied with age but the tendency, not surprisingly, was for jumping ability to mature with age in this sample (Table 2).

Table 1: Subject Characteristics (Means and Standard Deviations)

Age Groups	Age (mos)	Height (m)	Weight (kg)	Jump Height (m)	PE Classes (#/week)[1]	Youth Sport Seasons[2]	Activity Instruction Classes[3]
4-5 yrs (n = 6)	65.0 (5.48)	1.1 (.04)	19.6 (.76)	0.21 (.03)	0.3 (.52)	0.5 (.84)	1.8 (2.14)
6-7 yrs (n = 5)	85.8 (8.96)	1.2 (.06)	21.9 (1.07)	0.21 (.05)	1.4 (.89)	2.0 (1.87)	2.2 (1.48)
8-9 yrs (n = 3)	107.7 (4.16)	1.3 (.03)	23.3 (.47)	0.25 (.04)	1.0 (0.0)	6.7 (4.93)	1.0 (1.41)
Total (n = 14)	81.6 (18.16)	1.2 (0.10)	21.2 (1.72)	0.22 (.04)	0.9 (.77)	2.4 (3.32)	1.9 (1.73)

[1] Structured physical education classes in a private or public school setting. [2] Number of seasons [3] Number of class units.

Table 2: Sagittal View Differences in Jumping Characteristics Across Age Groups

Jumping Characteristic	Mature Level	All Ages (%) (69 landings)	4-5 yrs (%) (29 landings)	6-7 yrs (%) (25 landings)	8-9 yrs (%) (15 landings)
Knees > 90^o	Low	43	52	60	0
Knees 60^o-90^o	High	57	48	40	93
Too much trunk lean	Low	12	14	16	0
Arms aid unequally	Low	88	100	92	60
Arms coordinated	High	10	0	8	33
Leg tuck	Low	9	21	0	0

Landing observations from the sagittal plane indicated difficulty with the task (Table 3). Only 6% of all landings included a simultaneous touch of both feet and then a stop. The oldest age group accomplished this task most often. In 80% of all landings, simultaneous touch of both feet was followed by a step before stopping. All age groups stepped back more often than stepping forward. Other stepping patterns and directions (e.g., 2 steps forward) were evident but not tallied. These findings suggest that simultaneous control of balance and force absorption during landing was difficult. Balance was maintained as none of the participants fell. Landings consistently (99%) showed toe to heel contact, with foot placement mostly straddled (left (L) to right (R) or R to L) as opposed to side-by-side. Asymmetric foot placement may promote unequal force distribution between R and L legs. Less than 50% of all landings showed at least 30^o of knee flexion (FX) at IC, with little variation across age groups. However, with age, a greater percentage of landings showed at least 45^o of knee FX at MxKFx. Few landings (33%) showed hip FX at IC, but most landings (61%) showed increased hip FX from the time of IC to MxKFx. More knee and hip flexion allows more time to absorb landing forces. This positive landing trait may be more prevalent as children age.

Table 3: Sagittal View Landing Characteristics Across Age Groups

Landing Characteristics	All Ages (%) (69 landings)	4-5 yrs (%) (29 landings)	6-7 yrs (%) (25 landings)	8-9 yrs (%) (15 landings)
Simultaneous: 2-ft touch – stop	6	3	0	20
Simultaneous: 2 ft touch - 1 step[a,b]	80	86	92	60
[a]Step forward	17	17	28	7
[b]Step back	54	55	64	53
Toe-to-heel contact	99	100	96	100
Straddled (L-R)/(R-L)	46/29	38/44	56/24	47/7
IC: Knee 30^o FX	43	41	48	40
MxKFx: Knee 45^o FX	72	59	76	93
IC: Hip some FX	33	38	32	27
MxKFx: Hip > FX	61	45	76	67

Frontal plane observations showed that in each age group foot placement was at or greater than shoulder width (SW) in the majority of landings (Table 4). Children may use this placement coupled with a straddled foot position to control side-to-side and front to back balance. In only 30% of landings were one or both toes turned in or out at IC. This could be a positive trait as toeing in/out rotates the tibia, stressing the knee joint. In each age group, toeing in/out most often affected just one foot, promoting landing asymmetry. Only 35% of landings demonstrated knee valgus (VAL) at IC, but the oldest age group had the most instances of knee VAL at IC (73%). By the time of MxKFx, 39% of landings showed knee VAL for one leg, but with increasing age instances of knee VAL increased (28% to 40% to 60%). This finding is troubling as knee valgus may increase ACL injury risk in adolescence.

Table 4: Frontal View Landing Characteristics Across Age Groups

Landing Characteristics	All Ages (%) (69 landings)	4-5 yrs (%) (29 landings)	6-7 yrs (%) (25 landings)	8-9 yrs (%) (15 landings)
Stance: $\geq$ SW	68	79	52	73
Stance: <SW	32	21	48	27
IC: Toe out/in (1 foot)	28/29	38/24	24/24	13/47
IC: Toes out/in (2 feet)	9/14	3/21	20/8	0/13
IC: Knee VAL (1 or 2)	35	24	24	73
MxKFx: Knee VAL(1)	39	28	40	60
MxKFx: Knee VAL(2)	26	31	16	33

CONCLUSION: Sagittal and frontal view examination of children aged 4-9 jumping then landing indicated that the MVJ task presented similar levels of difficulty across age groups, despite a tendency for more mature jumping patterns with age. Landings did not seem to improve with age. The stop-landing task challenged balance as most landings included a step, straddled foot position, and wide stance. Knee and hip flexion mechanisms for force absorption tended to occur more often in landings of older children, but incidences of knee valgus also tended to increase with age. Findings are preliminary, yet highlight the need for further investigation to establish developmental expectations for landing that might allow potentially harmful mechanics to be corrected as children age. Future findings could benefit physical educators and youth sport coaches and positively influence landing skill development in young children.

REFERENCES:

Ayalon, A., Ben-Sira, D., & Leibermann, D. Characteristics of landing from different heights and their relationships to various fitness and motor tests. *Physical Fitness and the Ages of Man: Proceeding of the Symposium of the International Council for Physical Fitness Research,* 1987; Jerusalem.

DiStefano, LJ, Padua, DA, DiStefano, MJ, & Marshall, SW. (2009). *Influence of Age, Sex, Technique, and Exercise Program on Movement Patterns After an Anterior Cruciate Ligament Injury Prevention Program in Youth Soccer Players*, *American Journal of Sports Medicine, 37*: 495-505.

Gallahue, DL & Ozmun, JD. (2006). *Understanding motor development: infants, children, adolescents, adults*. Boston: McGraw Hill.

Gilchrist, J, Mandelbaum, BR, Melancon, H, et al. (2008). A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. . *American Journal of Sports Medicine*, *36*, 1476-1483.

Hewett, TE, Myer, GD, & Ford, KR. (2006). Anterior cruciate ligament injuries in female athletes: part 1, mechanisms and risk factors. *American Journal of Sports Medicine*, *34*, 299-311.

Padua DA, Marshall SW, Beutler AI, Boling MC, Thigpen CA. (2007). *Differences in jump-landing technique between ACL injured and non-injured individuals: a prospective cohort study*. *Journal of Athletic Training, 42*, S85.

Padua DA, Marshall SW, Onate JA, et al. (2004) Reliability and validity of the Landing Error Scoring System: implications on ACL injury risk assessment. *Journal of Athletic Training, 39*, S110.

Wickstrom, RL. (1983). *Fundamental movement patterns*. Philadelphia: Lea & Febiger.