A BIOMECHANICAL COMPARISON OF DEVELOPMENTAL STAGES OF THE STANDING LONG JUMP

D. J. Wilson[1] and E. W. Brown[2]

[1]University of Missouri - Columbia
Columbia, Missouri, USA

[2]Michigan State University
East Lansing, Michigan, USA

INTRODUCTION

The use of staging criteria for classifying developmental changes in body configurations in the performance of fundamental motor skills is common. These stages are based on kinematic and kinetic variables associated with motor performance. In practice, however, the staging criteria primarily utilize qualitative methods of assessment. The purpose of this investigation was to determine the validity of a staging sequence by measuring the ability of the biomechanical parameters to discriminate between individual stages of motor performance.

METHODOLOGY

The standing long jump was chosen for this study. Seefeldt, Reuschlein and Vogel's (1972) whole-body configuration model was used. Thirty-three subjects (25 males and 8 females) between the ages of 4 and 7 years volunteered as subjects.

Kinematic data were collected using a 16mm LOCAM high-speed camera equipped with a F 12-1200 mm zoom lens. A film rate of 100 frames per second with a shutter angle of 120° and Kodak 125 ASA film was used. A timing light box capable of measuring up to .001 second and plumb line were placed in the field of view. Body segment markers (1/2 inch colored adhesive disks) were placed on the subjects to aid in the location of anatomical sites during digitizing. The film was projected onto a drafting table by a Van Guard Motion Analyzer and digitized using a Science Accessories sonic digitizer. Kinetic data were recorded via an on-line AMTI force platform and an IBM 9000 computer. Analysis was performed using specially written software including a double-pass Butterworth filter for data smoothing. Overall MANOVA's were performed on each set of variables (descriptive, kinematic, and kinetic) to control for the overall alpha level.

RESULTS

A summary of the descriptive variables by stage is given in Table 1. Percent body fat was calculated from anthropometric data. A non-significant Hotellings value ($F[9, 77]=1.23$, $p<0.289$) indicated that univariate analysis was unjustified.

Table 1. Means and standard deviations for subject descriptors.

Variable	Stage 1 (n=5)	Stage 2 (n=12)	Stage 3 (n=11)	Stage 4 (n=5)
Age (mths)	72.00±12.57	72.17±9.81	75.18±10.24	83.60±5.86
Weight (kg)	24.65±6.50	21.01±3.63	22.01±3.22	21.34±4.09
% Body Fat	23.72±3.95	22.72±4.34	22.98±4.43	18.87±1.95

The overall MANOVA for kinematic data produced a significant Hotellings value ($F[12, 74]=2.13$, $p<0.006$). The horizontal difference between the position of the toes and the center of mass of the subject (takeoff gain) was calculated at takeoff. Landing gain, the horizontal difference between the heels and the center of mass, was calculated at landing. Univariate ONE-WAY analysis of variance tests revealed that distance jumped ($F[3, 29]=5.03$, $p<0.006$) and landing gain ($F[3, 29]=6.65$, $p<0.001$) were significant at the 0.05 level. Means and Tukey post-hoc results by stage are shown in Table 2.

Table 2. Means and standard deviations for distance and position variables.

	Stage			
Variable	1 (n=5)	2 (n=12)	3 (n=11)	4 (n=5)
Distance Jumped (m)	$0.77_a \pm 0.25$	$0.95_a \pm 0.28$	1.06 ± 0.22	1.32 ± 0.15
Takeoff Gain (m)	0.01 ± 0.11	-0.01 ± 0.09	0.07 ± 0.10	0.07 ± 0.04
Landing Gain (m)	$0.35_b \pm 0.17$	$0.47_b \pm 0.16$	0.56 ± 0.14	0.77 ± 0.15

a $p<0.05$ (Stage 4); b $p<0.05$ (Stage 4)

ONE-WAY analysis of variance procedures indicated that the acceleration of the thigh ($F[3, 29]=3.91$, $p<0.019$), acceleration of the trunk ($F[3, 29]=3.10$, $p<0.042$), acceleration of the arms ($F[3, 29]=5.00$, $p<0.006$), and the acceleration of the forearms ($F[3, 29]=13.51$, $p<0.000$) were all significant at the 0.05 level. Tukey post-hoc results are shown in Table 3.

Table 3. Means and standard deviations for resultant accelerations at takeoff.

Variable (m/s^2)	Stage 1 (n=5)	Stage 2 (n=12)	Stage 3 (n=11)	Stage 4 (n=5)
Foot	29.70 ± 10.67	26.74 ± 7.21	27.85 ± 4.84	24.97 ± 6.46
Shank	16.56 ± 5.94	17.76 ± 5.03	19.27 ± 3.57	19.41 ± 2.18
Thigh	$6.16_a \pm 4.42$	8.69 ± 4.45	10.36 ± 3.67	14.18 ± 1.85
Trunk	$10.85_b \pm 2.04$	9.25 ± 2.14	9.01 ± 2.63	6.65 ± 1.18
Arms	$15.26_c \pm 5.47$	20.26 ± 4.14	23.89 ± 3.95	22.71 ± 4.26
Forearms	$17.66_d \pm 8.60$	33.61 ± 6.96	42.09 ± 7.66	41.36 ± 7.36
Head	15.22 ± 3.52	14.34 ± 3.04	15.08 ± 1.97	12.77 ± 2.35

a $p<0.05$ (Stage 4); b $p<0.05$ (Stage 4); c $p<0.05$ (Stages 3, 4); d $p<0.05$ (Stages 2,3,4)

The overall MANOVA for kinetic data produced a significant Hotellings value ($F[21, 65]=3.02$, $p<0.000$). ONE-WAY analysis of variance tests revealed that only the resultant force of the forearms was significant ($F[3, 29]=4.99$, $p<0.007$). Means, standard deviations, and Tukey post-hoc results are shown in Table 4.

Peak vertical forces were normalized to percent body weight for the attempts for maximal height (Pvf-h) and distance (Pvf-d). Peak propulsive force in the direction of the jump (Ppf-d) was also recorded. Magnitude (Rv-d) and angle (Af-d) of the resultant force vector was calculated at maximal propulsive force.

The MANOVA for peak ground reaction force variables produced a significant Hotellings value ($F[18,68]=3.14$, $p<0.000$). ONE-WAY univariate tests indicated that peak propulsive force (Ppf-d) ($F[3, 29]=15.67$, $p<0.000$), resultant magnitude of force

(Rv-d) ($F[3, 29]=3.56$, $p<0.026$), and angle of resultant magnitude of force (Af-d) ($F[3, 29]=3.55$, $p<0.025$) were all significant. Means, standard deviations, and Tukey post-hoc results are presented in Table 4.

Table 4. Means and standard deviations for kinetic variables.

Variable (N)	Stage 1 (n=5)	Stage 2 (n=12)	Stage 3 (n=11)	Stage 4 (n=5)
Force - Foot	62.05 ± 31.97	48.58 ± 16.15	53.46 ± 14.54	47.12 ± 18.82
Force - Shank	83.04 ± 56.04	75.11 ± 29.07	85.09 ± 22.58	85.71 ± 25.98
Force - Thigh	65.15 ± 68.01	73.19 ± 49.82	88.34 ± 35.03	116.06 ± 45.79
Force - Trunk	242.98 ± 98.10	181.28 ± 53.14	187.82 ± 73.75	130.90 ± 29.12
Force - Arms	44.93 ± 28.79	50.66 ± 15.71	62.81 ± 16.46	59.60 ± 18.36
Force - Forearms	31.29a ± 23.79	50.01 ± 16.81	63.97 ± 12.59	62.27 ± 17.24
Force - Head	142.27 ± 65.20	117.45 ± 31.62	125.85 ± 23.18	97.50 ± 25.01
Time (ms)	364.00 ± 73.60	369.58 ± 59.41	336.36 ± 59.54	420.00 ± 83.67
Pvf-h (%bw)	127.00 ±3 0.94	135.42 ± 22.41	157.27 ± 28.93	159.00 ± 33.80
Ppf-d (%bw)	30.00_b ± 11.73	67.50 ± 11.97	66.83 ± 10.55	63.00 ± 8.37
Pvf-d (%bw)	93.00 ± 27.06	123.75 ± 31.34	115.00 ± 25.59	107.00 ± 28.20
Rv-d (%bw)	97.81_c ± 29.12	142.19 ± 27.34	133.56 ± 24.53	125.40 ± 21.89
Af-d (°)	71.49_d ± 2.02	60.40 ± 7.93	61.40 ± 6.90	58.36 ± 8.81

a $p<0.05$ (Stage 3,4); b $p<0.05$ (Stages 2,3,4); c $p<0.05$ (Stage 2); d $p<0.05$ (Stages 2,4)

DISCUSSION

The results of this study indicate that the biomechanical parameters that discriminate between the stages of the standing long jump may be fewer than indicated in the descriptions by Seefeldt et al (1972). In particular, those parameters associated with the faster moving segments (e.g., arms, forearms) during the performance have a greater ability to discriminate between levels of ability. The ability of the landing gain to discriminate well between several stages indicates that the position at landing may be an important event in determining standing long jump ability. Previous staging criteria have focused mainly on the movement patterns up to the point of take off.

CONCLUSIONS

The biomechanical parameters used to describe motor skill staging sequences need further assessment. The validity of the staging criterion depend upon the unique classification of these variables within stages. This study has indicated that these variables are subject to further validity testing and possibly modification. The results of this study are limited due to small sample size. Additional subjects and three-dimensional analysis are suggested for further study.

REFERENCES

Seefeldt, V., Reuschlein, P., Vogel, P. (1972). Sequencing motor skills within the physical education curriculum. Paper presented at AAHPER, Houston, TX.