IDENTIFICATION OF FLOOR AND VAULTING APTITUDE IN 8-14 YEAR OLD TALENT-SELECTED FEMALE GYMNASTS

Elizabeth J. Bradshaw and Peter Le Rossignol
Deakin University, School of Health Sciences, Melbourne, Australia

Training programs can be designed and monitored to maximise high aptitude for floor and vault when the key attributes are identified, and then used to recognize apparatus ability in talent-selected gymnasts. The aim of this study was to identify the anthropometric and physical prerequisites for high difficulty floor tumbling and vaulting. Twenty female gymnasts performed handstand push-offs, single and multiple jumps on a portable Kistler force plate. The gymnasts were also examined when sprinting, vaulting, and performing broad jumps. Each gymnast's best vault, three best floor tumbling skills and their anthropometric characteristics were also recorded. High squat jump force and power, vault take-off velocity, and sprinting speed indicated vaulting talent. High vault running speed and reduced handstand push-off ground contact time indicated high floor ability.

KEY WORDS: gymnastics, vault, floor, jump, run, talent.

INTRODUCTION: Women's gymnastics comprises of four apparatus routines, the uneven bars, balance beam, floor, and vault. Elite female gymnasts are short in stature, light, and possess high levels of strength, power, flexibility, and agility (Bale & Goodway, 1990). These 'ideal' anthropometric characteristics and physical prerequisites for gymnastics underlie the talent identification process in countries such as Russia, Canada, China, and Australia (Petiot et al, 1987). Considerable variability exists in the ability of talent-selected gymnasts to perform each apparatus. The final two members of an Olympic team, for example, are often selected based upon the apparatus strengths required to support the existing members of the team. To enhance the performance of gymnasts for specific apparatus, key elements that maximise performance need to be identified. With the exception of the uneven bars, jumping movements are common to all apparatus. Critical to the ability to perform many of the complex skills in gymnastics, therefore, is the ability to take-off. Furthermore, the elastic characteristics of the take-off surfaces in floor and vaulting lead to similarities in movement patterns for these apparatus (Krug et al, 2001). The ability to take-off when measured by vertical jump height and handstand push-off distance relates to increased performance in basic vaulting (Sharma, 1992). In addition, numerous studies have indicated that high running and take-off velocities are a prerequisite for the performance of difficult vaults (e.g. Bradshaw & Sparrow, 2001[a]). Measures of single and multiple jumping performance, handstand push-offs, running speed, and take-offs from elastic surfaces, therefore, are hypothesised to be useful predictors for identifying vaulting ability. Due to similarities in jumping movements and take-off surfaces between vault and floor it was logical that the predictors may also relate to floor tumbling ability. Talent identification procedures warrant further attention to establish what apparatus talent-selected gymnasts possess the highest aptitude towards, to ensure that apparatus talent can be fully developed. The purpose of this study was to identify the anthropometric, velocity and power prerequisites for high difficulty floor tumbling and vaulting.

METHOD: Twenty national-class female gymnasts ranging in age from 8-14 years participated in the study. Each gymnast completed five trials of vaulting, sprinting, squat jumps (SJ), countermovement jumps (CMJ), broad jumps (BJ), and handstand vertical push-offs (HP). A series of five bent leg jumps (CJbRef), five straight leg jumps (CJs), and 30s of bent leg jumps (CJb) were also completed. An ISAK Level 2 anthropometrist measured each gymnast's height, weight, and bone lengths. The best vault that each gymnast could consistently perform during training was identified together with the best three floor tumbling skills. Infra-red timing lights (Swift, Australia) were placed every 6m to record the last 18m of the vaulting approach and sprints. During the vaulting trials one digital camera (50Hz Pal 15µm) was set-up to film the take-off from the board. A 3.0m high calibration rod (2.5cm^2)

marked with 0.5m intervals was filmed in two positions to provide a two-dimensional scale-reference for the stationary camera. The vertical jumping and handstand push-off trials were performed on a portable force plate (Quattro Jump, Kistler, Switzerland) sampling at 500Hz. A thin mat was placed on the force platform for the handstand push-off trials. The gymnasts placed magnesium chalk on the heels of their feet and performed the broad jumps on a carpeted landing mat. The jump distance was measured from the start mark where the gymnasts placed their toes, to the heels after landing. The gymnasts' take-off angle, horizontal and vertical take-off velocities were analysed from the stationary camera footage (Video Expert II software, New Zealand). The SJ's, CMJ's, CJbRef, CJs, and HP force curves were analysed to determine the vertical displacement, peak take-off force, ground contact time, and power (Kistler software, Switzerland). In addition, the first five jumps (F5) and the last five jumps (L5) of the CJb were also analysed. All force values were normalised to units of body weight (BW) and all power values normalised to units of Watts/kg. The gymnast's vault and three tumbling skills were coded utilising the Women's Artistic Gymnastics Code of Points 2001. The vaults were given a score out of 10.00 and the tumbling skills were given a score from 1 (Graded A) to 5 (Graded E). The maximum score that the gymnast could be given for floor tumbling was 15 for three E tumbling skills. Statistical analysis was conducted using SPSS 11.0 for Windows. All of the analysed predictors were tested for normality and age effects. Separate linear models were developed for each predictor using linear regression analysis, with performance score for vault or floor tumbling as the outcome variable. Age was controlled for in all models. The regression coefficient (β) for each predictor was multiplied by that predictors observed range to obtain comparable estimates of predictive strength. The linear models for each predictor were then ranked by their relative predictive strengths.

RESULTS AND DISCUSSION: The vaulting ability of the gymnasts ranged from a basic handspring with a value of 7.8 to a handspring piked full twist with a value of 9.8 (Average=8.66). An increase of 0.200 in vaulting ability score equates to, for example, the performance of a handspring piked salto instead of a handspring tucked salto. The key predictor of high vaulting aptitude was the squat jump, as shown in Table 1. An increase of

Table 1. The predictors of high vaulting aptitude. The regression coefficient (β) indicates the change in the vaulting ability score with an increase of one unit of the predictor .

Predictor	β	p-value	βx Range
SJ Power (Watts/kg)	0.139	0.002	1.607
SJ Force (BW)	0.945	0.002	1.414
Tibia/ Height (%)	0.153	0.008	1.410
RV Take-Off (m/s)	0.648	0.006	1.408
HV Take-Off (m/s)	0.532	0.006	1.372
Sprint (m/s)	0.774	0.009	1.151
CJb L5 Power (Watts/kg)	-0.223	0.001	-1.150
CMJ Power (Watts/kg)	0.086	0.010	1.145
Leg Length/ Height (%)	0.099	0.011	1.138
CJb F5 Force (BW)	-0.279	0.008	-1.098
HP Ground Contact Time (s)	-8.142	0.012	-1.050
Vault Run (m/s)	0.660	0.009	1.040

1BW of force and 1Watt/kg of power in the squat jump was indicated by the regression coefficient(β) to increase vaulting ability by 0.139 and 0.945 respectively. The squat jump as a key predictor of vaulting ability indicates that high concentric explosive strength is required for the take-off from the vaulting board. Krug et al (1998) demonstrated in vaulting that the motion of the gymnast on the take-off board is more of a tension-shortening cycle instead of a stretch-shortening cycle. During the compression of the take-off board the gymnast holds a relatively static position, whereas during repulsion the gymnast concentrically extends the body toward take-off. Bradshaw and Sparrow (2001) indicated that the duration of the repulsion phase during take-off from the vaulting board is directly related to increased performance. The squat jump, therefore, predicts vaulting ability as it measures the concentric shortening strength related to the second phase of board contact. Other predictors of vaulting ability included high resultant and horizontal take-off velocities during vaulting, increased sprinting and vault running ability, high countermovement jump power, and reduced ground contact time during handstand push-offs. Consistent with Bradshaw and Sparrow (2001[a]) the results indicate that running ability and a high velocity take-off from the board is fundamental for the performance of difficult vaults. The ability to execute quick handstand push-offs indicates quick explosive strength suitable for the table (or horse) contact phase of vaulting. The key anthropometric predictor of vaulting ability was a long tibia length in proportion to height indicating greater leverage suitable for running and jumping. The floor ability of the gymnasts ranged from a total score of 4 to a score of 14 (Average=8.85). A score of 4 comprised of a backward piked salto (score of 1), a backward stretched salto (score of 1), and a forward layout salto (score of 2). A score of 14 comprised

Table 2. The predictors of high floor tumbling ability. Targeting ability was the difference between sprinting ability and vault running ability.

Predictor	β	p-value	βx Range
Vault Run (m/s)	2.964	0.019	4.671
HP Ground Contact Time (s)	-31.503	0.019	-4.064
Femur/ Leg Length (%)	-0.394	0.012	-3.767
RV Take-Off (m/s)	1.712	0.019	3.719
Sprint (m/s)	2.431	0.013	3.615
CMJ Power (Watts/kg)	0.261	0.017	3.497
CJb L5 Force (BW)	-0.613	0.003	-3.162
CJb F5 Force (BW)	-0.710	0.008	-2.793
Targeting Ability (m/s)	1.707	0.011	2.677
CJbRef Power (Watts/kg)	-0.121	0.018	-2.635
VV Take-Off (m/s)	0.931	0.003	2.605
Arm Length/ Height (%)	0.575	0.019	2.260

of a backward stretched salto with a triple twist (score of 5), an Arabian double salto (score of 5), and a backward double pike salto (score of 4). An increase of 1.00 point in floor tumbling ability score equates to, for example, the performance of additional ½ to 1 twist to a backward stretched salto. The key predictors for floor tumbling ability, as shown in Table 2, were increased vault running speed, decreased handstand push-off ground contact time, increased resultant and vertical take-off velocity when vaulting, and increased countermovement jump power. An increase of 1m/s in vault running ability and a decrease of 0.01s in handstand push-off ground contact time was indicated by the regression coefficient (β) to increase floor tumbling ability score by 2.964 and 0.315 respectively. Vault running speed indicates the gymnast's ability to run fast when constrained by a target, the take-off board. Floor tumbling contains a component of target-directed running (Bradshaw & Sparrow, 2001[b]). The implicitly defined take-off point for the start of tumbling comprises the target. The anthropometric predictors of floor tumbling talent were a shorter femur in proportion to leg length, and longer arms in proportion to height. The descriptive data for each of the predictors for vault or floor tumbling ability are provided in Table 3. The decrease in anaerobic power performance with age indicates that the continuous bent leg jump tests are not a suitable apparatus talent identification predictor for use in biomechanical testing. Many of the other predictors are also affected by age, such as sprinting. In sprinting, therefore, the maximum value for each age group should act as a guide for identifying vaulting or floor tumbling ability. When the predictor is not affected by age then the maximum or minimum value for the entire group of gymnasts should be utilised as the guide for identifying talent.

Table 3. Descriptive data for the predictors with significant age effects labelled [A].

Predictor	8-10 Years (n=7)			11-12 Years (n=8)			13-14 Years (n=5)			Mean
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	
Arm Length/ Height (%)[A]	31.61	30.48	32.91	32.33	31.41	33.46	33.11	32.14	34.41	32.27
Femur/ Leg Length (%)	52.19	45.10	54.66	50.98	49.18	52.71	52.52	51.68	53.37	51.79
Tibia/ Height (%)	20.80	17.88	27.10	20.85	19.87	21.70	21.40	20.23	22.05	20.97
Sprint (m/s)[A]	6.45	6.01	7.15	6.54	6.12	6.90	6.93	6.51	7.50	6.60
Vault Run (m/s)	6.07	5.65	6.36	6.31	5.77	6.65	6.20	5.48	7.06	6.20
Targeting Ability (m/s)[A]	-0.38	-0.84	-0.06	-0.23	-0.48	0.27	-0.74	-1.29	-0.30	-0.41
HV Take-Off (m/s)[A]	5.47	5.03	6.56	5.85	5.29	6.47	6.58	5.94	7.60	5.90
VV Take-Off (m/s)[A]	3.11	2.44	3.87	3.77	3.42	3.99	2.99	1.58	4.38	3.34
RV Take-Off (m/s)	6.32	5.60	7.15	6.96	6.41	7.53	7.34	6.80	7.77	6.83
SJ Force (BW)	2.46	2.08	2.85	2.62	2.23	3.57	2.77	2.09	3.29	2.60
SJ Power (Watts/kg)[A]	17.78	13.90	21.68	18.82	14.52	23.64	21.07	17.30	25.46	19.02
CMJ Power (Watts/kg)[A]	22.05	18.34	27.06	24.50	21.36	29.40	25.70	23.10	31.74	23.94
CJbRef Power (Watts/kg)	24.13	17.74	39.52	24.11	20.38	30.12	23.71	21.14	28.06	24.01
CJb F5 Force (BW)	2.23	0.94	4.55	2.02	1.38	2.74	1.31	0.62	2.04	1.91
CJb L5 Force (BW)	3.18	0.85	4.15	3.46	1.59	5.83	1.84	0.68	2.96	2.96
CJb L5 Power (Watts/kg)	19.46	3.73	31.12	23.88	14.90	32.70	20.51	14.98	22.80	21.49
HP GCT (s)[A]	0.239	0.186	0.287	0.206	0.184	0.232	0.194	0.158	0.215	0.215

CONCLUSION: Anthropometric, velocity and power performance measures can be utilised effectively to identify high floor tumbling and vaulting aptitude in 8-14 year old female talent-selected gymnasts. The apparatus talent identification procedures were unobtrusive to the gymnast's regular training and may be beneficial as a guide to the coach and national sporting bodies in designing and monitoring training programs to ensure that apparatus talent is fully developed. Future research directions include the collection of more reference data on the predictors for use in floor and vault talent identification.

REFERENCES:

Bale, P. & Goodway, J. (1990). Performance variables associated with the competitive gymnast. *Sports Medicine*, **10**(3), 139-145.

Bradshaw, E.J. & Sparrow, W.A. (2001[a]). The approach, vaulting performance, and judge's score in women's artistic gymnastics. In; Blackwell, J.R. (Ed). *Proceedings of Oral Sessions. XIX International Symposium on Biomechanics in Sports.* June 20-26, 2001, 139-142.

Bradshaw, E.J. & Sparrow, W.A. (2001[b]). Effects of approach velocity and foot-target characteristics on the visual regulation of step length. *Human Movement Science*. **20**, 401-426.

Federation Internationale de Gymnastique (2000). *WAG 2001 code of points*. FIG, Switzerland.

Krug, J., Knoll, K., Kothe, T., Zocher, H-D. (1998). Running approach velocity and energy transformation in difficult vaults in gymnastics. In; Riehle, H.J. & Bieten, M.M. (Eds). *ISBS '98 Proceedings*. 160-163.

Krug, J., Minow, H-J., Jassman, P. (2001). Differences between jumps on hard and elastic surfaces. In; Blackwell, J.R. (Ed). *Proceedings of Oral Sessions. XIX International Symposium on Biomechanics in Sports*. June 20-26, 2001, 139-142.

Petiot, B., Salmela, J.H., Hoshizaki, T.B. (1987). *World identification systems for gymnastic talent*, Sport Psyche Editions, Montreal, Canada.

Sharma, R.C. (1992). Speed, take-off, and handpush-off abilities in gymnastic vaulting. *NIS Scientific Journal*. **15**(3), 1992, 104-109.