RELIABILITY OF A GYMNASTICS VAULTING FEEDBACK SYSTEM

Elizabeth Bradshaw[1,2], Patria Hume[2], Mark Calton[3] and Brad Aisbett[4]

[1]Centre of Physical Activity Across the Lifespan, School of Exercise Science, Australian Catholic University, Melbourne, Australia
[2]Institute of Sport and Recreation Research New Zealand, School of Sport and Recreation, Auckland University of Technology, Auckland, New Zealand
[3]Queensland Academy of Sport Gymnastics Centre, Sleeman Centre, Brisbane
[4]School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia.

The current study assessed the intra- and inter-day reliability of a custom-built gymnastics vaulting feedback system. The system is a coach-friendly customized infra-red timing gate and contact timing mat system operated by the coach to augment the feedback provided to gymnasts on their vaulting performance during regular training practice. Thirteen Australian high performance gymnasts (eight males and five females) aged 11-23 years were assessed during two training sessions (Day 1 and Day 2) at their regular training centre. The approach velocity and board contact time measures were found to be reliable measures during vault training, with measures of pre-flight and table contact time less consistent. Future research should examine the validity of these measures as a tool for monitoring vault training.

KEY WORDS: gymnastics, vault, velocity, biomechanics, performance.

INTRODUCTION: The men's and women's vault are a feature of any artistic gymnastics competition. Competitors sprint towards a take-off board, where they launch themselves onto a vaulting table and then into the air completing various acrobatic manoeuvres before landing on their feet. Successful performance requires the optimization of each aspect of the action; the run up (or approach), pre-take-off hurdle, take-off, pre-flight, table contact, post-flight, and landing. Recent research has attempted to quantify the relationship between each or multiple aspect(s) of the vault and overall performance (i.e., judges' score). For instance, Krug, Knoll and Zocher (1998) reported a moderate correlation ($r = 0.68$, $P < 0.01$) between average approach velocity and judges' score at the 1997 World Gymnastics Championships. Similarly, Bradshaw and Sparrow (2001) indicated that vaulting score ($r = 0.59$, $P<0.05$) was significantly correlated with a short board contact time, which in turn, was significantly correlated with post-flight time ($r = -0.41$, $P < 0.05$). A brief contact time on the take-off board and / or vaulting table is likely to translate the gymnasts approach velocity into a longer post flight time (Bradshaw, 2004) or distance, allowing the gymnast more time to complete more complex acrobatic manoeuvres in the air. This increases the degree of difficulty and the potential for high scores. The significant relationships between vaulting score and specific aspects of the gymnast's vault should compel coaches to monitor these variables as a part of training or routine testing.

Evaluating changes in performance predictive variables could highlight the gymnast's training progress between competitions. Instantaneous measurements of variables such as approach and take-off velocity, board and table contact time have not however been part of routine gymnastics aptitude testing. The reliance on descriptive or qualitative measures of vault ability has arisen, at least in part, from the absence of a valid, reliable system for measuring velocity and power in a training environment. The variability associated with predictors of vaulting aptitude using a novel timing system during training is unclear. Highly sensitive sports science measurements are characterized by little variation in consecutive measures of performance (Hopkins, 2000). The advantage of small test-retest variability between testing sessions is that any change in the athlete's performance can be confidently attributed to their recent training history, and not random fluctuations (Hopkins, 2000). Minimizing variability is also an advantage when monitoring fatigue or trialling interventions to improve performance. The change in performance due to the intervention has to be greater than the normal day-to-day training variation before coaches can conclude that the intervention has had a meaningful impact on the athlete's performance (Soper and Hume, 2004). The primary aim of the current study was to assess inter- and intra-session reliability of gymnast's approach velocity, board and vaulting table contact times, and pre-flight time using a novel timing system.

METHODS: Thirteen Australian high performance gymnasts (eight males and five females) aged 11-23 years who performed vaulting routinely participated in this study. The females were aged 14.6±2.5 years, 1.48±0.12 m tall, 42.2±12.1 kg in mass, and had a leg length of 0.78±0.08 m. The males were aged 15.8±3.9 years, 1.58±0.13 m tall, 50.2±12.2 kg in mass, and had a leg length of 0.79±0.05 m. All gymnasts were injury-free at the time of testing and capable of performing 2.4 or higher graded vaults according to the International Gymnastics Federation Code of Points 2005-2008. A Yurchenko layout (stretched) salto, for example, is graded as a 4.4 difficulty rating in women's gymnastics. The criteria for injury was when an athlete had not participated in training for more than seven days and/or had not participated in two sequential competitions at the time of testing (Noyes, Lindenfield, and Marshall, 1988). All procedures used in this study complied with the guidelines of the Australian Catholic University Ethics Committee and Auckland University of Technology Ethics Committee.

All participating gymnasts were measured for standing height, body mass, and leg length using the International Society for the Advancement of Kinanthropometry (ISAK) protocols (Marfell-Jones, 2006). The gymnasts were assessed during two training sessions (Day 1 and Day 2) at their regular training centre after a preceding familiarization training session (familiarization with the timing system). The gymnasts completed their general and vaulting warm-up under the supervision of their coach. Each gymnast completed a number of vault repetitions as per their normal vaulting training session. Vault category groups performed included: Handspring entry; Tsukahara entry; and Yurchenko entry. All vaults were maximal effort and separated by a 2-3 minute rest period, with a verbal "go" signal the only in-trial feedback. Each training session was completed within 60 minutes.

The experimental setup consisted of a set of seven Fusion Sport infra-red timing lights, a beat board and vaulting table with contact mats included. The Fusion Sport system (Fusion Sport, Brisbane, Australia) included single beam, timing gates with error correction, and contact timing mats. These devices provide timing information at a rate of 1.8 MHz. The beat board was an American Athletic Incorporated men's Stratum beat board (480 mm wide and 800 mm long). The Jansen Fritsen vaulting table had a customised Acromat vaulting table cover made of 35 mm aqualite foam (50 mm thick). The upper surface was of synthetic suede with the no-touch zone indicated with a red marking as usual for an Acromat vaulting table. Vinyl foot switch contact mats were inserted underneath the upper surfaces of both the beat board (Fusion Sport, Brisbane, Australia, Jump Mat 226554, 45.72 cm wide, 60.96 cm long, 1.3 cm deep, 6.35 kg) and the vaulting table (Fusion Sport, Brisbane, Australia, Jump Mat 210005, 69.85 cm wide, 82.55 cm long, 1.3 cm deep, 12.70 kg).

The variables of interest to this study were run-up velocities (at -18 to -12 m, -12 to -6 m, -6 to -2 m, -2 to 0 m from the beat board) and board contact time, pre-flight time (board take-off to table contact) and table contact time which could be used to quantify performance. Descriptive statistics for all variables are represented as mean and standard deviations. Data were log transformed to provide measures of reliability (e.g. difference in mean, typical error of measurement as a coefficient of variation percentage, Pearson correlation coefficients) (Hopkins, 2000). Measures of reliability were determined using a repeated measures analysis of variance. Mixed modelling statistical procedures were performed using SAS (Statistical Analysis System).

RESULTS AND DISCUSSION: This study quantified the variability in vaulting performance between two daily training sessions with the main measures of interest, in terms of reliability, being the typical error of measurement as a coefficient of variation (CV%) and 90% limits of agreement (LOA) for the approach velocity, pre-flight time, and board and table contact time variables of vault performance.

Table 1. Mean, standard deviation and variability statistics for the handspring vault for males and females combined performed across two consecutive days of training.

Male and Female	Day 1 (n=22)		Day 2 (n=16)						
Handspring vault	Mean	SD	Mean	SD	Mdiff (%)	Typical error as a CV (%)	Limits of agreement (%)	Pearson r	ICC r
-18 to -12 m	4.33	0.83	4.28	0.82	1.8	16.0	56.4	0.52	0.45
-12 to -6 m	6.32	0.25	6.23	0.17	-1.7	1.9	5.8	0.72	1.00
-6 to -2 m	6.51	0.26	6.46	0.28	-2.4	3.6	11.1	0.18	0.29
-2 to 0 m	6.07	0.22	6.02	0.28	-2.5	3.4	10.5	0.22	0.32
Board contact time	0.12	0.01	0.12	0.01	0.4	4.3	13.4	0.54	0.46
Pre-Flight time	0.28	0.04	0.29	0.05	1.7	15.6	54.9	0.25	0.32
Table contact time	0.14	0.05	0.13	0.03	4.7	22.7	85.2	0.30	0.48

Table 2. Mean, standard deviation and variability statistics for the Yurchenko layout full twist for females across two consecutive days of training.

Female	Day 1 (n=7)		Day 2 (n=7)						
Yurchenko layout vault	Mean	SD	Mean	SD	Mdiff (%)	Typical error as a CV (%)	Limits of agreement (%)	Pearson r	ICC r
-18 to -12 m	5.30	0.79	4.98	0.64	-5.74	16.7	70.6	-0.10	-0.10
-12 to -6 m	6.64	0.10	6.80	0.09	2.33	1.0	3.6	0.50	0.49
-6 to -2 m	6.86	0.07	6.83	0.58	-0.82	5.6	20.8	0.71	0.17
-2 to 0 m	5.17	0.45	5.88	0.51	12.42	8.0	32.2	0.25	0.24
Board contact time	0.14	0.00	0.14	0.01	1.13	6.9	30.2	-0.82	-0.69
Pre-Flight time	0.23	0.08	0.18	0.03	-20.26	28.6	139.0	0.08	0.07
Table contact time	0.10	0.01	0.11	0.02	27.0	5.5	160.6	0.00	0.07

Table 3. Mean, standard deviation and variability statistics for the Tsukahara layout for males across two consecutive days of training.

Male	Day 1 (n=5)		Day 2 (n=10)						
Tsukahara layout vault	Mean	SD	Mean	SD	Mdiff (%)	Typical error as a CV (%)	Limits of agreement (%)	Pearson r	ICC r
-18 to -12 m	5.75	0.05	6.05	0.21	3.2	1.4	5.6	-0.82	0.76
-12 to -6 m	7.30	0.19	7.29	0.38	-4.9	2.1	8.4	-0.02	0.80
-6 to -2 m	7.65	0.31	7.97	0.44	0.4	3.2	13.1	-0.09	0.63
-2 to 0 m	7.49	0.18	6.92	0.26	-5.9	2.6	10.5	-0.14	0.44
Board contact time	0.12	0.00	0.12	0.01	-4.1	4.0	16.6	0.51	0.50
Pre-Flight time	0.11	0.03	0.10	0.02	4.9	33.6	211.5	-0.27	-0.55
Table contact time	0.22	0.03	0.23	0.03	-4.6	16.4	81.7	-0.57	-0.37

The variation in gymnastics performance for the handspring (males and females combined), Yurchenko layout (females only), and Tsukahara layout (males only) are summarised in Tables 1-3 respectively. When testing during a training session, a much higher level of technical (biological) variation could be expected due to the gymnast and coach focusing upon different aspects of their vault performance. The vault tests are therefore not pure repeats, but working trials to improve aspects of technical execution. A standard error of measurement of 10% or less is considered small in pure test-repeats of three or more trials (Bennell et al., 1999).

The performance variation was generally small across days for the velocity measures of the vault approach (Average CV= 5.45%). The least variation (CV=1.4%, LOA=5.6%) was observed during the first 6 m of the run-up (-18-12 m segment) of the males Tsukahara tuck vault and the least reliable (CV=16.7%, LOA=70.6%) being the same segment during the females Yurchenko layout vault. The difference in reliability for velocity during the initial phase of the vault could have been due to the younger age of some of the female gymnasts performing the Yurchenko vault and different acceleration rates. Measures of board contact time from the contact mat built into the beat board were considered adequately reliable for all vaults tested (CV=4.0-6.9%, LOA=16.6-30.2%). Whereas pre-flight and table contact time revealed less favourable results with a CV as high as 33.6% found for pre-flight during the Tsukahara layout vaulting. High pre-flight variation could be due to variations in angular rotation between gymnasts and also vault techniques. Large variation in hand placement technique on the vault table was observed. The youngest females (aged 11 years) often brushed the table with their fingers (‘fingered’), as opposed to contacting the table with the full hands. Differing table contact techniques was also observed between the male and female gymnasts, with great variation within the male gymnasts. Table contact time was not adequately reliable for the handspring vaults performed by the males and females (CV=22.7%) but was reliable for the Yurchenko layout vaults performed by the females (CV=5.5%).

CONCLUSION: This study has revealed that velocity measures from timing gates when combined with a contact mat embedded into the beat board can be reliably used to assess vaulting performance during training. Improvements in testing precision are required for measurements of pre-flight and table contact time. Test of these two factors may require competition simulation- style testing where the gymnast performs pure repeats, as opposed to working (training) trials. Further research should examine the validity of the vault timing system for individual gymnasts’ performance by assessing changes in these measures with training.

REFERENCES:

Bennell, K., Crossley, K., Wrigley, T. and Nitschke, J. (1999), Test-retest reliability of selected ground reaction force parameters and their symmetry during running. *Journal of Applied Biomechanics*, *15*, 330-336.

Bradshaw, E.J. (2004). Target-directed running in gymnastics: A preliminary exploration of vaulting. *Sports Biomechanics*. *3*,125-144.

Bradshaw, E.J. and W.A. Sparrow (2001). The approach, vaulting performance, and judge’s score in women’s artistic gymnastics. In; *International Society of Biomechanics in Sport 2001: Scientific Proceedings*. University of San Francisco.

Hopkins, W.G., (2000). Reliability from consecutive pairs of trials. In; *A new view of statistics*. sportsci.org: International Society for Sport Science.

Krug, J., K. Knoll, and H.-D. Zocher. (1998). Running approach velocity and energy transformation in difficult vaults in gymnastics. In; *XVI Symposium on Biomechanics in Sport Proceedings*. Konstanz, Germany.

Marfell-Jones, M.J., Olds, T., Stewart, A.D. and Carter, L. (2006). *International Standards for Anthropometric Assessment*. Potchefstroom, South Africa: International Society for the Advancement of Kinanthropometry (ISAK).

Noyes, F.R., T.N. Lindenfeld, and M.T. Marshall (1988). What determines an athletic injury (definition)? Who determines an injury (occurrence)? *American Journal of Sports Medicine*, *8*, S65-68.

Soper, C. and P.A. Hume (2004). Reliability of power output during rowing changes with ergometer type and race distance. *Sport Biomechanics*. *3*, 237-247.