TAKE-OFF KINEMATICS OF BEAM DISMOUNTS

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The technical criteria for the successful execution of beam dismount take-offs are essentially similar to those of floor take-offs. However, the physical limitations imposed by the beam restrict the gymnast in a number of practical ways. Beam length, width and stiffness are factors not encountered on the floor. These factors therefore change the take-off technique greatly although the skills essentially 'look' the same. At the World Gymnastics Championships in 1994, the beam final was filmed and analysis carried out on the dismounts of the eight finalists. All gymnasts completed double backward somersault dismounts. Data revealed that the vertical velocity of the centre of mass (CM) at take-off ranged from 2.65 to 3.42m/s, with a mean value of 3.01 ± 0.22m/s. These values are considerably lower than those achieved for similar skills on the floor. The mean value for the horizontal velocity of CM at take-off was 1.89 ± 0.29m/s. A number of gymnasts demonstrated the ability to increase the CM horizontal velocity whilst in contact with the beam during take-off. The maximal height of the CM above the floor was recorded at 2.61 ± 0.07m. Staggered hand and feet positions were necessary because of the beam width which reduced the effectiveness of the take-off.

INTRODUCTION

Although the skills learnt on the floor are generally applied to the beam, the technique required to successfully complete these skills is quite different. The physical limitations imposed by the beam on the gymnast ensure that this straight forward crossover of skills is not possible. Balance is of vital importance and much more critical on the beam than the floor. On this point alone the two apparatus are inherently different.

In a study of three female gymnasts, (Weber and Knoll, 1989) analysed backward somersault dismounts on the beam and floor. Limited kinematic data was reported with the most significant results indicating the maximal height of the CM during dismount of 1.57m above the level of the beam for the Tsukahara dismount, and 1.55m for a double back tucked salto dismount. A similar study by (Thiess, 1992) analysed backward acrobatic movements on the beam by 20 subjects. Thiess theorised that on the floor maximal horizontal velocity is generated in the preparatory movement before the final or dismount salto. On the beam, it was suggested that the aim of the gymnast is to obtain an optimal relationship between vertical and horizontal velocity. Unlike the take-off position on the floor for a backward salto, the gymnasts CM is behind the base of support at take-off on the beam. This maintains a relatively high level of CM horizontal velocity at the last contact. Because of this, Thiess indicated that a special take-off technique is required for the beam. Unfortunately, the author does not present any kinematic data to support these theories. In Brueggemann's paper on gymnastic techniques (1994), concurrence with (Thiess, 1992) was expressed in that there are few similarities between backward take-offs from the beam and the take-offs on the floor.

METHODS AND EQUIPMENT

Subjects

The dismounts of the eight beam finalists were used in the analysis. Data pertaining to these gymnasts and their performance in the final is detailed below.

No.	Gymnast	Country	Dismount	Score	Rank
399	Miller	USA	Tsukahara tucked	9.875	1
394	Podkopayeva	UKR	Tsukahara tucked	9.737	2
386	Fabrichnova	RUS	Tsukahara tucked	9.712	3
383	Hategan	ROM	double back tucked	9.687	4
380	Milosovici	ROM	double back tucked	9.675	5
398	Dawes	USA	Tsukahara tucked	9.650	6
375	Qiao	CHN	double back piked	9.212	7
338	Strattmann	GER	double twist layout	8.650	8

Table 1. Beam: Individual Apparatus Finalists Details

Equipment and data capture

The beam final at the 1994 World Gymnastics Championships was filmed using two Panasonic PAL F-15 cameras positioned in the catwalks above the competition floor. The competition area was lit by high power television lighting. The cameras were genlocked and time synchronised using an Event Synchronisation Unit and EBU time code generators. The EBU time code was recorded on the audio track of the videotapes (channel 2).

In order to reconstruct the gymnasts position in three dimensional space from two 2-D camera views, the PEAK system calibration frame consisting of 24 spheres of known co-ordinates was filmed to obtain a calibration and scaling factor. This provided an approximate calibrated space of 2.05m x 2.05m x 1.3m. The long horizontal axis of the calibration frame was approximately aligned with the long axis of the beam.

Data analysis

Analysis of all performances was completed using the PEAK Technologies Motion Analysis System V5. The 2-D co-ordinates of a 21 point body model were manually digitised (effective half-pixel resolution 1024 x 1024). The raw co-ordinates were filtered using a Butterworth low pass digital filter with an optimal cut-off frequency determined by the Jackson 'knee' method (1973). Total body centre of mass position was determined based on the anthropometric data of (Dempster, 1955). The differential process employed provided the kinematic data (Miller and Nelson, 1973).

RESULTS AND DISCUSSION

The most important take-off parameters from the beam dismounts were identified and reported in Table 2.

Parameters	Means	SD
Max. CM height during dismount (somersault) flight (m)	2.62	0.07
CM height at take-off (m)	2.21	0.05
CM vertical velocity at take-off (m/s)	3.01	0.22
CM horizontal velocity at touch-down for take-off(m/s)	1.77	0.38
CM horizontal velocity at take-off (m/s)	1.89	0.29
CM to ground contact and the horiz. at TD for TO (°)	100	7
CM to ground contact and the horiz. at take-off (°)	86	4
Trunk to horizontal take-off (°)	71	9
Trunk to horizontal at touchdown for take-off (°)	121	9
Contact time during take-off (s)	0.12	0.03

Table 2. Means and Standard Deviations of Selected Take-Off Parameters from the Beam Dismount Performances.

Analysis of the data revealed that the most important factor influencing somersault height, CM vertical velocity at take-off, ranged from 2.65 - 3.42m/s, with a mean value of 3.01m/s. The maximal height of the CM above the floor reported a mean value of 2.62m (range 2.48 - 2.73m) which is some 1.42m above the level of the beam. This value is slightly below that reported by (Weber and Knoll, 1989). The difference between CM height at take-off and CM maximal height in flight is 0.41m. This is a relatively low value which can be attributed to the reduced capacity of the athlete toproduce high vertical velocity at take-off because of the physical limitations imposed by the apparatus and the resultant change in technique.

Of most interest in the current data was the trend of gymnasts to increase the horizontal velocity of the CM between touchdown for take-off and last contact. Figure 1 illustrates how the gymnast is in contact with the beam for an extended period during take-off. During this time the position of the trunk changes dramatically. The data shows that the position of the trunk changed by a mean of 50° during this contact time of around 0.12s. This resulted in a change in mean CM horizontal velocity from 1.77m/s at touchdown to 1.89m/s at last contact.

The trunk position at take-off (71° ± 9) and the CM to ground contact angle at take-off (86° ± 4) reveal that the CM is behind the base of support at take-off as first theorised by

(Thiess, 1992). This would mean that the vertical ground reaction force vector would be passing anterior to the CM. The CM to ground contact angle measures the position of the CM in relation to the feet. An angle greater than 90° illustrates that the CM is anterior to, or in front of, the feet, whilst the reverse is the case for an angle less than 90". For the beam finalists the range for this parameter was between 81 and 92°, with only two of the gymnasts achieving values greater than 90".

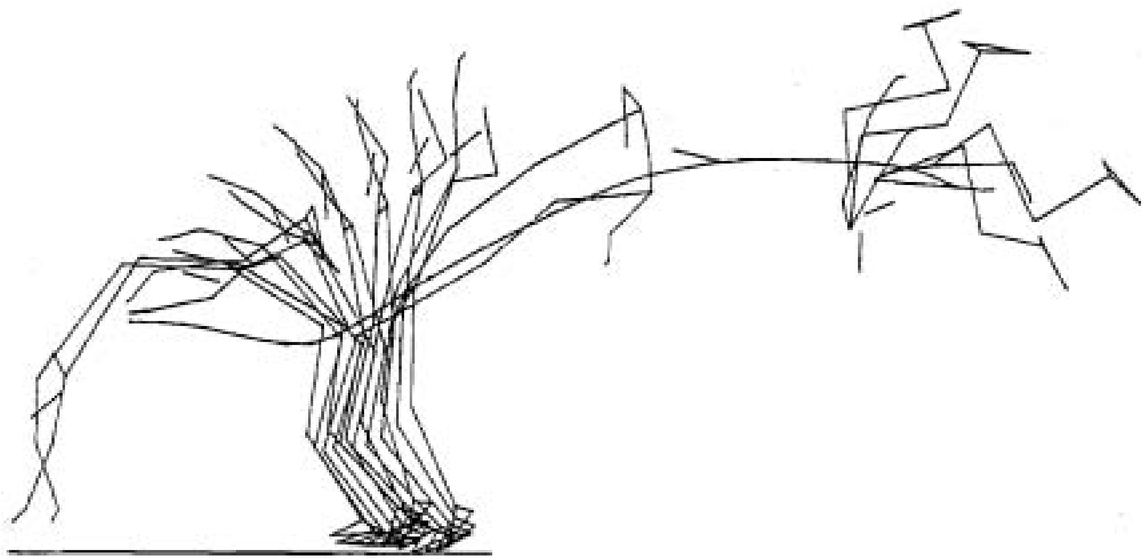

Figure 1: Stick figure representation of beam dismount

CONCLUSION

The physical characteristics of the beam compromise the gymnasts ability to produce optimal vertical velocity during take-offs. The staggered hand and feet positions which are vital to maintain balance during preparatory skills and the stiffness of the beam reduce the effectiveness of the take-off in comparison to the floor. As a result CM vertical and horizontal velocity components are comparatively less than those achieved for the same skills on the floor.

In order to execute a successful beam dismount, it is important that the gymnast establish high initial energy conditions through an effective round off and/or back handspring before take-off. This is achieved by staggering the hands and feet with minimal separation at placement. During take-off a powerful trunk snap up combined with extension at the hip, knee and ankle joints is vital.

REFERENCES

Brueggemann, G. P. (1994). Biomechanics of gymnastic techniques. In Sport Science Review. 3, (2) 79-120.

Dempster, W. T. (1955). Space requirements of the seated operator. Aerospace Medical Research Laboratory, Wright Paterson AFB, Ohio.

Jackson, K. M. (1973). Fitting of mathematical functions to biomechanical data. IEEE Trans. Biomedical Engineering, 122-124.

Miller, D. I. & Nelson, R. C. (1973). Biomechanics of Sport. A Research Approach. Philadelphia: Lea & Febiger.

Thiess, P. (1992). New trends in acrobatic elements on the beam. In G. -P. Brueggemann & J.K. Ruhl (Eds.), Biomechanics in Gymnastics-Conference Proceedings (pp. 129-138). Koln: Strauss

Weber, R. and Knoll, K. (1989). Balance Beam. In G-P. Brueggemann and J. Krug (Eds.) The World Championships in Artistic Gymnastics-Scientific Report.