DIRECT FORCE MEASUREMENT OF THE VAULT TAKE OFF IN GYMNASTICS

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INTRODUCTION

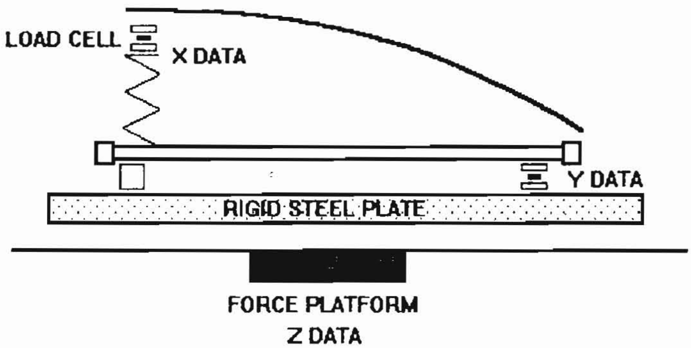
The take off from the springboard in gymnastics vaulting is a critical part of the whole vault. It is during this phase that the gymnast must convert the mostly linear momentum created during the run up into the appropriate ratio of both linear and angular momentum required for successful completion of the vault.
Some research work has focused on various aspects of the whole vault (Takei, 1988, 1989; Takei & Kim, 1990; Nelson et al, 1985; Dillman et al), showing that parameters related to the take off phase such as contact time, contact and take off angles and contact times are closely correlated to the score awarded by the judges. Few studies, have attempted to investigate closely the forces involved with this part of the vault (Kreighbaum, 1974; Gao and Bruggeman, 1993).
The purpose of the present work was to conduct an analysis of the kinetic characteristics of the take off phase of vaulting and the forces occurring within the springboard itself.

METHODS

The inverse dynamics approach to force analysis, which had been used in the majority of previous work who's purpose was to analyse the complete vault, proved to be problematic when undertaking an in depth analysis of the force characteristics taking place during the vault take off. This was due to the short time phase of the springboard contact which has been consistently reported as having a duration of 0.100-0.130s^{-1} (ibid). The high sampling rate required to prevent aliasing, resulted in a low signal to noise ratio in the second derivative of time displacement data.
Piezoelectric devices have long been used in force platforms but individual Piezoelectric load cells are relatively new in sports biomechanics applications.
In order to produce reliable and valid data, the load cells must be preloaded in a non elastic jig. This ensures that all force is transmitted through the cell and not absorbed by it. Two Kistler load cells (type 9134a) were preloaded in a steel jig and placed between the upper surface and the spring mechanism of a Gymnova competition springboard (model B219). Two load cells were also pre loaded and situated under the feet at the rear of the springboard. The springboard itself was attached to a Kistler force platform by means of a rigid steel plate, in order to record Ground Reaction Forces. The experimental set up can be seen in figure 1, below.
Eight male gymnasts, all members of the Great Britain Under 15 squad (mean mass 47.5Kg SD 7.8Kg) each performed five handspring vaults under laboratory conditions. The run up length was at the discretion of each gymnast. The vaulting horse was fixed at competition height (1.35m). Data was captured at a nominal rate of 800Hz, using three Kistler charge amplifiers (Type 5001) and an IBM PS2 computer with an internal analogue to digital converter. The data was recorded and plotted using bespoke software. Three data channels recorded: (X) the sum of

the two load cells placed above the spring; (Y) the sum of the two cells placed under the rear feet of the board and (Z) the vertical ground reaction force.

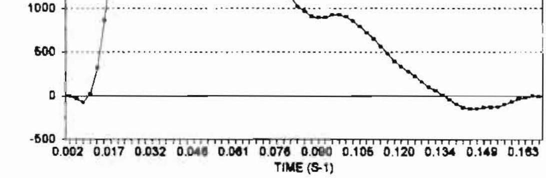
Figure 1



The trials were also filmed at 250Hz using a Kodak Ektapro high speed video system. The camera was placed perpendicular to the centre of the springboard with the subject visible throughout the contact phase.
The force data were smoothed in a spreadsheet package using a simple 3 point moving average before interpretation.

RESULTS

Figures 2,3 and 4 show the mean force traces for all trials for the X,Y and Z data channels, respectively.

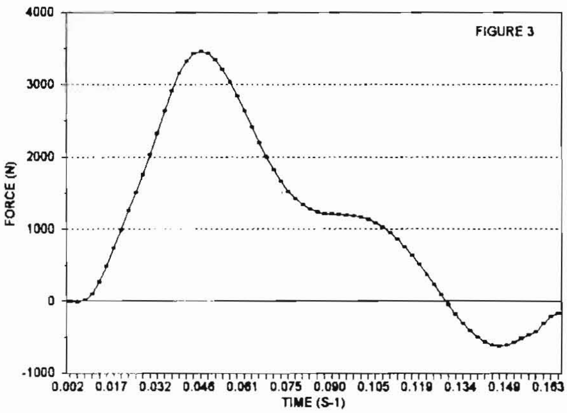


The mean initial peak was found to be 2891N, which was equivalent to 6.1 times the mean mass of the eight subjects. This peak occurred 0.02secs after contact and was attributed to the natural oscillation of the upper surface of the board combined with the effect of the contact point of the gymnasts on the board (mean 0.56m SD 0.10m from front edge).

This submaximal peak was followed by a larger peak (mean 3334N) equivalent to 7 times body mass. This peak occurred 0.05 secs after contact and coincided with the maximal deflection of the board.

This peak was followed in many trials by a linear reduction in force to a point approximately 0.09 secs after contact where a partial deweighting took place. This deweighting of the load cells was seen at the time where the gymnast's Centre of Mass passed vertically above the base of support. It was following this partial deweighting that the majority of the hip, knee and ankle extension occurred.

Neither the submaximal or maximal peak was significantly correlated to either contact time or mass. However a mildly significant result was obtained between the maximal and submaximal peaks ($p=0.10$), unlike the results obtained by Kreighbaum (1974). The partial deweighting observed was in agreement with the findings of Kreighbaum (1974), although the absolute values differed due to differences in methodology.

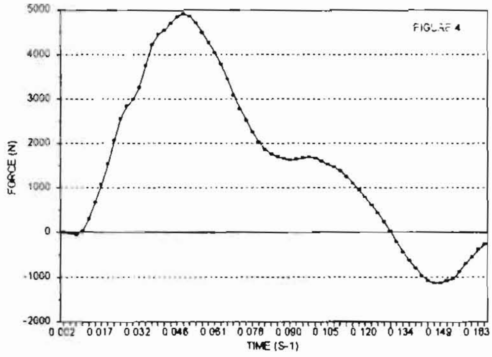


The load cells placed under the feet of the springboard produced a mean maximal peak force of 3458N. This peak again coincided with the maximum deflection of the upper surface of the board. A partial deweighting of the load cells was also seen as the gymnast's Centre of mass passed over the feet.

No significant correlations were found between any of the measured parameters and these force data.

The mean maximal peak ground reaction force of 4911N (10.3 times body mass) was recorded by the force platform as the gymnast reached maximal deflection of the board.

All three data channels recorded negative force readings, following the gymnast's take off, of up to 1138N.



CONCLUSIONS

The data recorded do not necessarily represent the forces which the gymnast is subjected to, but their magnitude should be of concern in relation to both potential trauma and overuse injuries, particularly in young gymnasts.

The negative values recorded after take off, represented force which is not being transferred to the gymnast and therefore could be regarded as an inefficiency in the system, which has possible design implications.

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