AN ACCURATE ESTIMATION OF THE SPRINGBOARD REACTION FORCE IN VAULTING TABLE OF GYMNASTICS

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The purpose of this study was to establish the measurement method of the reaction force from the springboard used in vaulting table of gymnastics. Ten male gymnasts?performed the handspring vault. The springboard was mounted on four force plates. The ground reaction force was obtained at 1000Hz. A high-speed camera at 500Hz sampled the springboard motion. The springboard was modeled as, 1) twenty-nine segment model consisting of three boards, 2) twelve segment model consisting of upper board, 3) two segment model consisting of upper board and 4) one segment model consisting of upper board. Board reaction forces of these models were calculated from GRF and accelerations of segments. Results indicate that the simpler two segment model can be used to accurately calculate the BRF as same as the complicated model (twenty-nine segment).

KEY WORDS: gymnastics, vaulting table, springboard, reaction force.

INTRODUCTION: In vaulting table of gymnastics, effective use of the reaction force from the springboard is important factor for performance. In an actual vaulting, the springboard plays an important role; act to absorb the impact force in its deforming process and to achieve higher vaulting in its rebounding process. Thus, the actual force from the springboard can not be measured by recording the ground reaction force only. For this reason, actual aspects of reaction force from the springboard have never quantified properly. The purpose of this study was to establish the measurement method of the reaction force from the springboard used in vaulting table of gymnastics.

METHODS: Ten male gymnasts volunteered to participate in this study. After an adequate period of warm-up, they were performed handspring vault at least five times. All performances were awarded the scores by a judge. A performance awarded the best score per subject was analyzed. The springboard (Senoh, AJ0504) was mounted on four force plates (Kistler, 9281B). The springboard was consisted of three boards (upper, middle and lower) and two springs. The ground reaction force (GRF) was obtained by sum up data from four force plates sampled at 1000Hz. A high-speed video camera was used to sample the springboard motion at 500Hz. The optical axis of the camera was perpendicular to the plane of motion. Reflective markers (1cm in radius) were fixed on the side of boards at 10 cm intervals. The length of the upper, middle and lower board were 120cm, 50cm and 120cm length respectively, thus the number of fixed markers was thirteen, six and thirteen respectively. These markers were digitized from twenty frames before touch-down to twenty frames after take-off. The two-dimensional coordinates were smoothed by a fourth-order Butterworth low-pass filter. The cut-off frequencies were selected automatically for each coordinate (Winter, 1990). Upper, middle and lower boards were modeled in the links of 10cm length rigid segments, thus modeled in twelve, five and twelve segment model respectively (Figure 1 (a)). The acceleration of center of each segment was calculated from film data. Board reaction force (BRF) was calculated as follows:

$$BRF = GRF - Mg - \sum m_i a_i$$

where M is mass of the spring board, g = acceleration of gravity, m_i is mass of i-th segment and a_i is acceleration of center of i-th segment.

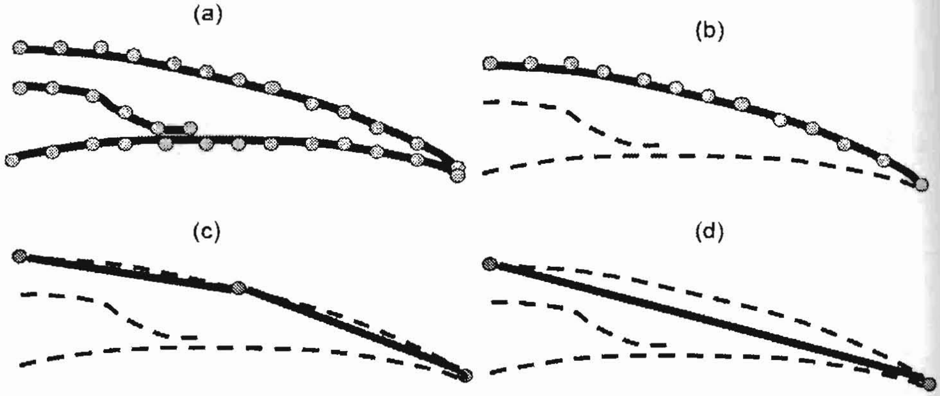

Figure 1: Models of the springboard. (a) Consist of 10cm length rigid segments. (b) Twelve segment model consist of upper board only (c) Two segment model consist of upper board only (d) One segment model consist of upper board only.

The springboard was modeled in four types. That is, 1) twenty-nine segment model consist of all of three boards (Figure 1 (a)), 2) twelve segment model consist of upper board only (Figure 1 (b)). 3) two segment model consist of upper board only (Figure 1 (c)) and 4) one segment model consist of upper board only (Figure 1 (d)). Then, board reaction force of these models (BRF_all, BRF_upper12, BRF_upper2 and BRF_upper1 respectively) was calculated by equation 1.

RESULTS AND DISCUSSION: Figure 2 (a) showed the average (+ SD) of the vertical component of BRF_all and GRF from touch-down to take-off. This is the evidence that the change of BRF is substantially differed from that of the GRF.
Since the effective mass of the middle board and the vertical motion of the lower board can be very smaller than those of upper board, the changes of BRF_all and BRF_upper12 were quite similar in almost all time (Figure 2 (b)). Therefore, the effect of the middle and lower board can be negligible in BRF calculation process.

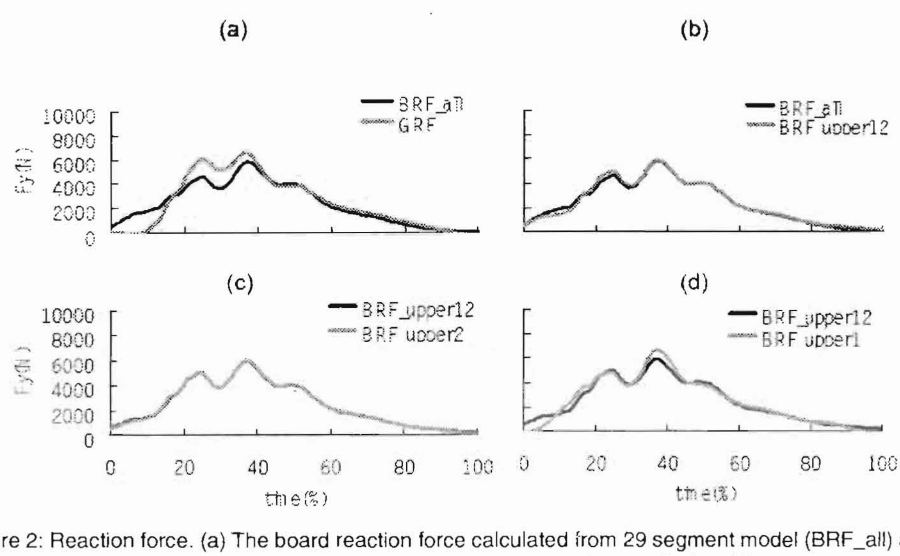

Figure 2: Reaction force. (a) The board reaction force calculated from 29 segment model (BRF_all) and the ground reaction force (BRF). (b) BRF_all and the board reaction force calculated from 12 segment model consist of upper board only (BRF_upper12). (c) BRF_upper12 and the board reaction force calculated from 2 segment model consist of upper board only (BRF_upper2). (d) BRF_upper12 and the board reaction force calculated from 1 segment model consist of upper board only (BRF_upper1).

Figure 2 (c) indicates a very close BRF association between the 12 and 2 segment models. This indicated that the simpler model consist of only two segment has enough accuracy as same as the complicated model consist of twenty-nine segments. On the other hand, the change of BRF_upper1 failed to follow the change of BRF_upper12 (Figure 2 (d)). This discrepancy most likely due to the fact that the simplest (one segment) model could not account for the deformation of the upper board.

It is expected that the more complicate the model of the springboard, the more accurate the data calculated from force plate and film data in a theoretical sense. On the other hand, complicated model increase the amount of digitization and the time of analysis. Increasing the time of analysis prevent immediate feedback for athletes. In the present study, the (simple) 2 segment model had similar accuracy as the 12 segment (complicated) model.

CONCLUSION: The BRF was measured from force plate and film data. The change of BRF was differed from the change of GRF substantially. The BRF calculated from simple model (two segment model) had enough accuracy as same as that from complicated model (twenty-nine segment model). This result suggested that the time of analysis must be reduced. Therefore, immediate feedback of the accurate data could be done for athletes by use of two segment model.

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