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Relationship between angular displacement of shoulder joint and force acting on the pole in the pole vault

Kageyuki, T.1, Kigoshi, K.2, Yokozawa, T.1

1 Japan Institute of Sports Sciences, Tokyo, Japan; 2 University of Tsukuba, Ibaraki, Japan

INTRODUCTION:
The bending of the pole is the one of the main factors determining the maximum height of the vaulters centre of gravity in the pole vault. The bending of the pole is caused by the conversion of the mechanical energy of the vaulter, in particular the translational energy, into the elastic energy of the pole (1)(2). Although it has been suggested that the action of the shoulder joint muscles was important in exerting force on the pole (3), the vaulters motion in relation to the force acting on the lower tip of the pole, the box reaction force, has not been elucidated. Therefore, the aim of this study was to investigate the relationship between the angular displacement of the shoulder joint and the box reaction force.
METHODS:
14 Japanese male pole vaulters (season record = 5.22±0.19m) performed trials with run-up steps and poles identical to those used in competition. Three-dimensional body coordinates were obtained using a motion capture system (250 Hz) and the box reaction force was measured using a force platform (1000 Hz). The global coordinate system was defined as the Y axis in the direction of the progress of the run-up, the Z axis in the vertical upward direction, and the X axis as the cross product of the Y and Z axes. Several events were defined; pole plant (PP), take-off (TO), maximum vaulter's angular momentum (MAM) and maximum pole bending (MPB) (2). MAM was the instant when the vaulters swing motion was represented and was defined as the instant when the vaulters angular momentum peaked (2). The shoulder joint angle was defined as the angle between the long axis of the upper trunk and the long axis of the upper arm around the traverse axis of the upper trunk (flexion +/ extension -). The impulse of the box reaction force between each event was calculated using a fourth-order Runge-Kutta method. Pearsons correlation coefficient was used to analyse the relationships between the variables.
RESULTS:
The results were summarised as follows:
1) The impulse of the Y-component of the box reaction force (Fy) from PP to MPB was negatively correlated with the elastic energy in the pole at MPB ($r=-0.57$, $p<0.05$).
2) The angular displacements of both shoulder joints from MAM to MPB were negatively correlated with the impulse of Fy from PP to MPB (upper: $r=-0.54$, $p<0.05$; lower: $r=-0.62$, $p<0.05$).
3) The average angular velocity of the shoulder joint on the lower grip side from MAM to MPB was negatively correlated with the impulse of Fy from PP to MPB ($r=-0.56$, $p<0.05$).
CONCLUSION:
These results suggest that the phase from MAM to MPB is the important in causing the pole to bend. In addition, considering the muscle force-velocity relationship, there seems to be a specific vaulting technique and shoulder strength that leads to an increase in the box reaction force. The results of this study would have practical implications for pole vault training.
REFERNCES:
1) Arampatzis et al., J. Biomech, 2004
2) Kageyuki et al., Int. J. Sport Health Sci., 2020
3) Hubbard, J. Biomech., 1980

Topic: Biomechanics

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