Factors influencing performance in gymnastics vaulting--- computer simulation models

- Reporter : Hui-Chieh Chen
- Adviser : Bruce Cheng
Outline

- Introduction
- Literature review
- Summary
- Future directions
Introduction

- **Vault**
  - **Continuous rotation**
    - the somersault rotation continues in the same direction (e.g. handspring vault)
  - **Counter rotation**
    - the direction of rotation is reversed during contact with the horse (e.g. Hecht vault)
Introduction

- The five phases of Hecht vault

(Takei et al., 2000)
Introduction

- The ability to perform a vault depends on several factors
  - the pre-flight parameters at horse contact
  - the elastic properties of the horse and the gymnast
  - the joint torques exerted while in contact with the horse

(king et al., 1999)
Sprigings et al., 1997

- Two-segment model
- Without using shoulder torque during horse contact phase
Literature review (1)

- Arm fixed
- High horizontal velocity is needed
- In practice, gymnasts use arm circling in post-flight to aid rotation and land at a suitable angle
Literature review (2)

- Yeadon et al., 1998
  - Pre-flight characteristics of Hecht vaults
  - two-dimensional video analysis
  - gymnasts performing the Hecht vault had longer, lower and faster preflights with slower rotation at horse contact compared to handspring somersault vaults.
Literature review (3)

- king et al., 1999
  - Two-segment simulation model
  - The Hecht vault required
    - A low trajectory of the mass centre during pre-flight
    - A low vertical velocity of the mass center and a low angular velocity of the body at horse contact.
Literature review (3)

- The handspring somersault required
- A high pre-flight trajectory
- A high angular velocity of the body and a high vertical velocity at horse contact.
Takei et al., 2000

- The mechanical variables that govern success of the Hecht vault
- 122 male gymnasts at the 1995 World Gymnastics Championships
- Correlational analysis was used to establish the strength of the relationship between the mechanical variables identified in the model and the judges’ scores
- Significant correlations ($P < 0.005$)
Important determinants:

- large horizontal and vertical velocities at take-off from the board and the horse
- large vertical and angular distances of pre-flight
- large vertical impulses of high force and short duration exerted on the horse contact and the resulting large changes in vertical velocity
- large horizontal and vertical distances and long times of post-flight
king et al., 2005

- Two-segment models ignore
  - the effect of the hands, shoulder torque
  - elasticity of the horse and gymnast
  - changes in the hip and knee angles during the contact phase

Thus, it is necessary to use models with more segments.
Literature review (5)

- Five-segment models of the Hecht vault
- Hand, arm, trunk+head, thigh and shank+foot
- Massless non-linear springs
  - Arm-horse interface
  - Glenohumeral joint
-Torque generator
  - Shoulder extensor
Literature review (5)

- Customised to a elite gymnast
- Segmental inertia parameters
- One performance was recorded by two camera (200Hz and 50Hz)
- Strength measurements was taken by an isovelocity dynamometer
- Autolev
Input
- Contact with the vaulting horse:
  - mass center velocity, orientation of each segment, angular velocity of each segment
  - initial activation, onset time, ramp time, final activation level for the torque generator

Output
- takeoff from the vaulting horse:
  - whole body angular momentum about the mass centre
  - mass centre velocity
  - orientation and angular velocity of each segment
The overall agreement between the actual performance and the matching simulation was sufficiently good to allow the subject-specific simulation model to be used.

Potential limitation of simplicity:
- The assumption of using rigid links
- The lack of a rigid hand segment and wrist joint
- The lack of active forces to resist movement at the shoulder joint
- The lack of shoulder elasticity in line with the body has only a small effect
## Literature review (5)

- **Fixed hip and knee angle**

### Comparison of actual performance and simulations

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Literature review (5)

- Fixed hip and knee angle
  - Changes in the hip or knee angles while in contact with the horse doesn’t affect greatly
  - Not necessarily require separate segments for the thighs and lower legs + feet
## Literature review (5)

- No shoulder torque

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No shoulder torque

- The matching simulation used 30% maximal shoulder torque
- the shoulder torque used during the contact phase had only a small effect
No hands

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Literature review (5)

- No hands
  - contact time $\Downarrow$ angular momentum $\Downarrow$
  - the angular momentum at takeoff (backwards somersault rotation) was 15% smaller $\rightarrow$ 15° less backwards rotation than the matching simulation
### Literature review (5)

#### Stiff shoulders

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- **35% ↓**
- **67% ↓**
Stiff shoulders
- 50% less rotation
- had a large effect on performance
Shoulder angle

- Initial shoulder angle at touchdown → backwards rotation during the contact phase
- Handspring is possible
Implication of the result

- confirmed that the use of shoulder torque plays a minor role in vaulting performance
- having appropriate initial kinematics at touchdown is essential
- factors such as shoulder elasticity and the hands which have previously been ignored also have a substantial influence on performance.
Summary

- A simple model cannot be used to determine optimum approach velocity, but can be used to understand some of the basic principles involved in vaulting (King et al., 2005).

- More complex simulation models will match the actual performance better and have more insight into the vault.
Future directions

- Elite gymnasts in Taiwan
- Handspring vaults and high difficulty level vaults
- 11-segment simulation model
- 3D analysis
- Muscles or torque generators at more joints
Thanks for your attention!