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ENERGY DISSIPATION WHILE LANDING FROM A JUMP

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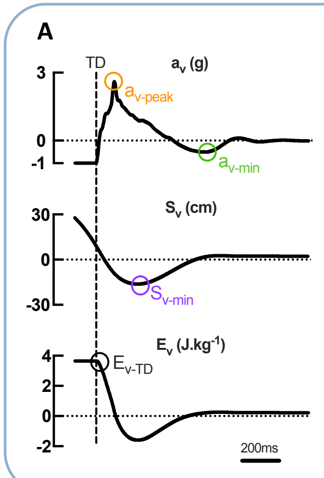
Introduction

When landing from a jump, we must be able to slow down our body and dissipate the energy accumulated during the fall in order to reach back a stable standing position (SP) without rebounding or losing balance. In order to dissipate energy, our body biomechanical behavior must switch from a spring to damped harmonic oscillator throughout landing (Gambelli et al. 2015). When landing from different heights, the control must be adjusted to the amount of energy to be dissipated.

Aim: analyze the biomechanical adjustments in relation to the amount of energy to dissipate while landing on the ground.

Methods

- **Participants**: 14 young healthy adults (age: 22-31 yo)
- **Task**: Jump from a box of different heights (10, 30, 60cm) and land on both feet in a natural way
- **Measurement**: ground reaction force (GRF)
- **Variables**: max/min value of the vertical acceleration ($a_{v\text{-peak}}$; $a_{v\text{-min}}$) of the center of mass of the body (CoM), lowest position reached by the CoM ($S_{v\text{-min}}$), amount of energy at touchdown ($E_{v\text{-TD}}$), stiffness from touchdown (TD) to $a_{v\text{-peak}}$ (k_1), stiffness and damping coefficients (k_2 ; c_2) from $a_{v\text{-peak}}$ to SP.



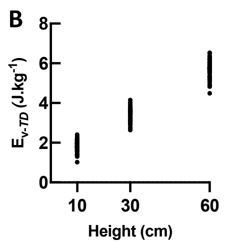


Fig. 1 A: Typical trace of a landing from a jump of 30cm. Vertical acceleration (a_v), displacement (S_v) and energy (E_v) of the CoM as function of time. TD: touchdown.
Fig 2 B: Amount of energy to be dissipated as function of height.

Results

As the amount of energy to be dissipated increases:

- k_1 remains constant while k_2 and c_2 decrease.
- The model is fitting well with the data (mean r^2 =0.93 for k_1, 0.94 for k_2 & c_2);
- $a_{v\text{-peak}}$ increases, $S_{v\text{-min}}$ decreases while $a_{v\text{-min}}$ remains constant.

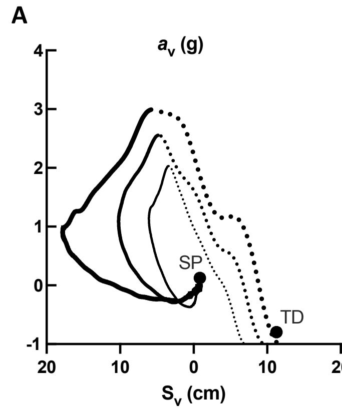


Fig. 2 A: Grand-mean curves of a_v as function of S_v from TD to SP. Thick line: 10cm; normal line: 30cm; thin line: 60cm. Dotted line: spring like phase; solid line: damped phase. Spring equation: $a_v = k_1S_v$ + intercept ; damped harmonic oscillator equation: $a_v = k_2S_v + c_2V_v$ + intercept.

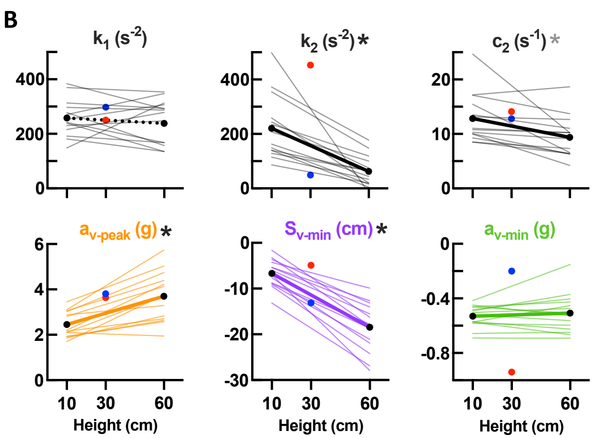


Fig 2 B: Biomechanical properties (k_1, k_2, c_2) and CoM behavior ($a_{v\text{-peak}}$, $S_{v\text{-min}}$, $a_{v\text{-min}}$) as a function of height. Thin line : each participant; thick line: grand mean of all participants. On each graph: two behaviours are illustrated : "unsafe" in red ($a_{v\text{-min}}$ close to -1g); "safe" in blue.
*: p<0.01 ; *: p<0.001

Discussion

To avoid rebound, the biomechanical properties seem be tuned to get a constant safety margin* rather than to reduce the mechanical constraints. Indeed, $a_{v\text{-min}}$ remains constant, whereas the impact of the ground increases as the energy to be dissipated increases. Each participant seems to have his own constant safety margin regardless of the amount of energy.

* If a_v reaches -1g, the participant will loose contact with the ground, so $a_{v\text{-min}}$ reflects the risk of rebounding (safe vs unsafe behaviour).

The illustration of 2 different behaviours highlights the necessity to diminish the stiffness k_2 (damped phase) in order to get a safety margin (Figs 2 & 3: "unsafe" in red; "safe" in blue). The "unsafe" behavior is characterised by a stiff behaviour and a small lowering of CoM (S_v), whereas the impact peak ($a_{v\text{-peak}}$) is similar for both trials.

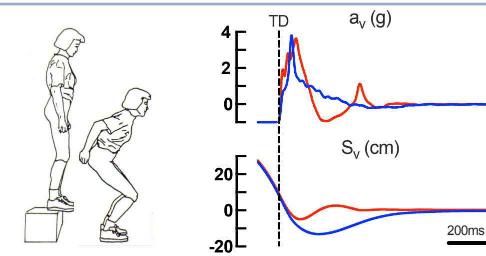


Fig. 3 Typical traces of two behaviours (30cm): "unsafe" in red; "safe" in blue. a_v and S_v as function of time. The characteristics are illustrated in Fig. 2 B.

In conclusion, energy dissipation requires a fine tuning of biomechanical properties of the body during the second part of landing (i.e., damped phase) in order to dissipate the correct amount of energy.

Gambelli, C. N., D. Theisen, P. A. Willems, and B. Schepens. 2015. 'Motor Control of Landing from a Jump in Simulated Hypergravity', *PLoS One*, 10: e0141574.

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