The Lower Limb Mechanical Response at Landing from a Jump in Children Discloses Two Different Strategies for Adapting to Unloading

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Introduction

In performing daily activities of mobility, such as stair descent, we are often challenged to complete the task in a variety of environmental contexts that may not be predictable. These locomotor activities rely on our ability to adjust our balance to the support surface conditions in order to preserve upright stability. An important determinant of balance control is to regulate the position of the body center of mass (COM) to maintain its relationship to the base of support. The factors affecting the control of balance at the environmental interface are: 1) the intrinsic mechanical properties of the leg; 2) the conditions of external load application; and 3) the supraspinal and reflex neural mechanisms of the leg muscles. However, the relative contribution of these factors to the dynamic control of balance remain to be elucidated. The objective of our study was to examine the relationship between the mechanical response of the lower limbs and the conditions of external load application during the impact phase of landing from a jump in children.

Methods

Eight healthy children aged 7.5 to 10.5 years (weight: 24 to 41 kg; height: 1.25 to 1.53 m) were asked to perform 5 sets of 10 jumps from a block of 25 cm high. They were instructed to keep their legs together during flight and land on both feet with a foot on each of two adjacent force platforms. For each series, a percentage of their body weight (BW) was supported by a harness attached to a pneumatic support system. Unloading levels were varied from 0%BW (child accepts full body weight at landing) to 40%BW (child accepts 60% of body weight at landing) by increments of 10%. Body kinematics were captured at 120 Hz by a 6-camera VICON 512 Motion System and a set of 27 reflective markers placed over specific anatomical landmarks. Ground reaction forces and moments were acquired at 1080 Hz by two AMTI force plates embedded in the landing surface. The position of centre of mass (COM), and angular displacements, moments and forces at the hip, knee and ankle joints were obtained from a model using the BodyBuilder software (Oxford Metrics, Ltd.).

Results and Discussion

Displacement profiles of the COM for various unloading conditions illustrate the change imposed to COM vertical displacement when the level of unloading increases (Fig. 1). Increasing the level of unloading produced a gradually increasing overshoot of the vertical displacement of the pelvis COM in 4 of the 8 subjects. This increasing overshoot was associated with a decrease in the downward excursion of the pelvis COM after impact and reduced ranges of angular displacements, mostly at the knee joints. The marked modulation of pelvis COM excursion with unloading resulted in a constant impact force for the children presenting profiles with overshoot. The kinetic data

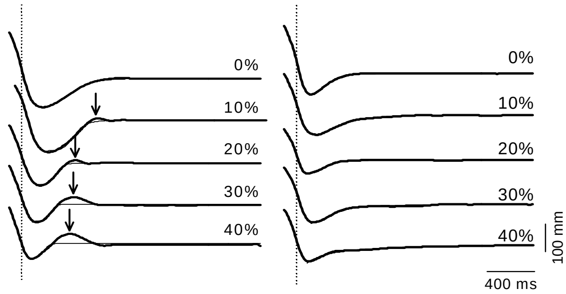

Figure 1. Typical COM displacement profiles with (left panel) and without (right panel) overshoot (shown by the arrow) for unloading conditions from 0 to 40%BW. The vertical dotted lines indicate the time of impact with the ground. The displacement of the COM (thick lines) was fitted by exponential curves (thin lines), showing ideal stabilisation profiles (no oscillation).

revealed a modulation of the moments at the hip, knee and ankle joints, and two different patterns of adjustment of the lower limb stiffness with unloading. Indeed, the COM displacement profiles with overshoot were associated with increasing lower limb stiffness with unloading whereas the COM displacement profiles without overshoot were associated with a decreasing lower limb stiffness with unloading (Fig. 2).

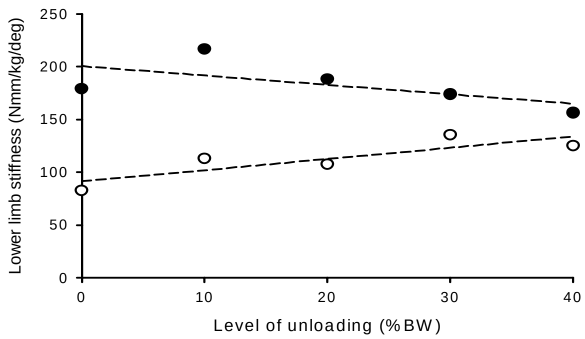

Figure 2. The global stiffness of the lower limbs across the level of unloading for a child presenting profiles with overshoot (open circles) and a child presenting profiles without overshoot (closed circles).

Conclusion

Two strategies can be adopted by children when adjusting their lower limb mechanical response to unloading when landing from a jump. These strategies consist in either decreasing or increasing the lower limb stiffness. However, the second strategy may lead to more instability as shown by the overshoot in the COM displacement profiles.

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