Bouncing on the Moon: joint power during walking, running, and skipping in emulated low gravity.

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Summary

Gravity shapes how we move and at what cost. On the Moon, humans shift from walking to bouncing gaits, and low gravity reduces the metabolic cost of running and skipping more than walking. Why does gravity's effect differ between gaits? We calculated joint power at the ankle, knee, and hip for walking, running, and skipping on the Earth and at emulated Mars and Moon gravities. Lowering gravity reduced the mechanical power of running and skipping more than walking. Power production also shifted from distal to proximal joints for walking, but the opposite occurred for bouncing gaits. These findings may explain why reducing gravity leads people to progressively prefer bouncing gaits over walking.

Introduction

Humans walk and run on Earth, but astronauts adopted unilateral skipping in Moon missions [1]. Low gravity reduces the metabolic cost of bouncing gaits more than that of walking, and decreases the body centre of mass work for all gaits [2]. However, its effect on individual joint power is unknown. Understanding it could help optimise countermeasures for astronauts, and body-weight support systems for clinical rehabilitation. Here, we studied how gravity affects ankle, knee, and hip joint power in walking, running, and skipping.

Methods

Five participants (3 female; 31.2±6.2 y) walked at 1.39 m s^{-1}, and ran and skipped at 2.50 m s^{-1} for 20 seconds on an instrumented treadmill (Bertec). Locomotion was performed on Earth (1.00g) and at Mars (0.38g) and Moon (0.17g) gravities emulated with a weight suspension system [2], while 24 cameras tracked 68 bilateral markers. Inverse kinematics and dynamics were performed with OpenSim 4.4 using a scaled model [3]. Joint moments were multiplied by joint angular velocities to obtain instantaneous joint power, and time-integrated and divided by stride duration to get average joint power. Power at the three joints was summed to provide total mechanical power [4]. A linear mixed model regressed power against gravity, with participants as random effects.

Results and Discussion

Lowering gravity decreased total mechanical power more in bouncing gaits (fixed effect: 2.8 W kg^{-1} g-$level^{-1}$; intercept: 0.1 W kg^{-1}) than walking (0.8 W kg^{-1} g-$level^{-1}$; 0.2 W kg^{-1}). Gravity also influenced the relative contribution of each joint to total power differently across gaits. In walking, positive power production shifted from the ankle and knee to the hip at lower gravity levels. In contrast, for running and skipping, the proportion of ankle power relative to knee and hip increased at lower gravity levels (Fig. 1).

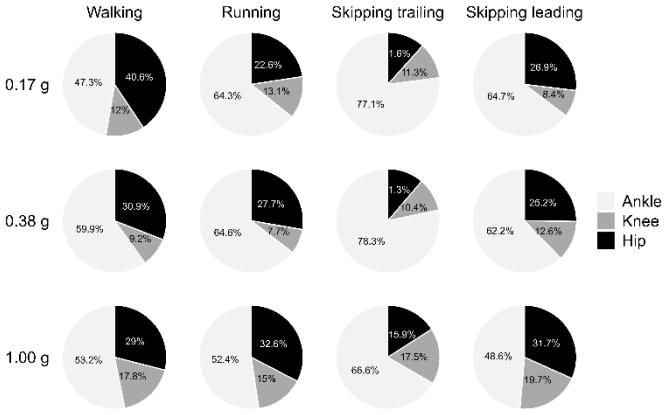

Figure 1: Percentage of total average positive power at the ankle, knee, and hip joints with varying gravity.

Conclusions

Low gravity decreases total joint power more in bouncing gaits than in walking. Moreover, it redistributes power production from distal to proximal joints for walking, and from proximal to distal ones for running and skipping. The impact of gravity on mechanical work may explain why bouncing gaits are preferred under low gravity.

References

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