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From Trot to Skip: Mice Adopt Human-like Hypogravity Gait in a Lunar Gravity Harness

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Abstract

Human astronauts on the lunar surface spontaneously skip rather than walk or run, driven by the six-fold reduction in gravitational loading. Whether quadrupeds display an analogous locomotor reorganisation under hypogravity is unknown. Here we simulated lunar gravity ($\approx 16.5\%\, g$) in treadmill-running mice using a custom elastic harness, and characterised the resulting gait with markerless motion capture and comprehensive kinematic analysis. We first located the center of mass at 50.8% of body length, providing a geometric basis for harness placement. Under simulated lunar gravity, mice displayed several hallmarks of skipping: a 2.5-fold increase in bilateral aerial time, a near-doubling of stride-to-stride cycle irregularity, threefold increases in hindlimb paw lift and base of support, and a significant elevation of the energy recovery ratio. Inter-limb phase coordination was globally disrupted, with all three coupling directions showing significantly reduced phase concentration under hypogravity. An unbiased multiple factor analysis of 104 locomotor parameters confirmed fully distinct locomotor states ($R^2 = 0.638$, $p = 0.001$). These results provide the first evidence that a skip-like gait is not unique to bipeds but is an emergent quadrupedal response to reduced gravitational loading.

Keywords: *hypogravity, locomotion, skipping, gait, mouse, spring-mass model, partial weight-bearing*

1. Introduction

On April 1, 2026, the Artemis II mission carried four astronauts on a ten-day journey around the Moon — the first crewed flight beyond low Earth orbit since Apollo 17 in 1972, and the opening act of a planned era of sustained human presence on the lunar surface. As agencies prepare for crews who will live and move under lunar gravity ($g_{\text{Moon}} \approx 0.16\, g_{\text{Earth}}$), a basic biological question becomes urgent: how does the locomotor system reorganise in a gravitational environment so different from the one in which it evolved?

The mechanics of legged locomotion are deeply governed by gravity. Two fundamental mechanisms dominate. In walking, the body vaults over a relatively stiff supporting limb — an inverted-pendulum mechanism — exchanging gravitational potential energy (tied to height) and kinetic energy (tied to speed) out of phase to minimise muscular work[1]. In running and trotting, the centre of mass bounces like a pogo-stick: potential and kinetic energy vary in phase while elastic energy is transiently stored and returned by muscles and tendons[1]. In both cases, gravitational acceleration sets the characteristic timescales: it determines preferred stride frequencies, optimal speeds, and ground reaction force magnitudes. Reducing gravity does not simply make movement easier; it fundamentally rescales every mechanical relationship that governs coordination and stability.

This sensitivity is dramatically illustrated by the behaviour of Apollo astronauts on the lunar surface. At low to moderate speeds, they spontaneously adopted skipping rather than walking or running[2, 3]. Skipping is a bilaterally asymmetric gait in which a walking-like double-support phase alternates with a running-like aerial phase, and in which one leading limb consistently produces a longer stride than the trailing limb, resulting in a characteristic long-short cycle alternation[2]. The name is doubly literal: one skips off the ground, and skips over the alternation — each limb taking two consecutive beats (L–L–R–R) rather than alternating at every step (L–R–L–R). Crucially, skipping simultaneously exploits both the pendulum-like and elastic energy-saving mechanisms, making it the mechanically optimal gait in reduced gravity[2]. Whether an analogous gait reorganisation occurs in quadrupeds under similar gravitational conditions is entirely unknown.

In quadrupeds, gait is characterised by the inter-limb phase relationships within a stride cycle[4] (the normalised delay between two limbs' touchdowns: $0 =$ synchrony, $0.5 =$ perfect alternation). The trot, the preferred attractor gait of mice at moderate speeds, is defined by anti-phase coupling between left and right hindlimbs ($\phi_{\text{HL}} \approx 0.5$) and in-phase coupling between diagonal pairs ($\phi_{\text{diag}} \approx 0$)[4]. The bound is equally well defined: both hindlimbs move in synchrony ($\phi_{\text{HL}} \approx 0$) and both forelimbs in synchrony, with a half-cycle offset between fore and hind pairs.

To study hypogravity locomotion without access to space, researchers have developed ground-based partial weight-bearing (PWB) systems. Early designs relied on tail suspension, which restricts natural quadrupedal locomotion and redistributes load toward the forelimbs[5]. Subsequent spring-based harnesses improved range of motion but suffered from daily drift in unloading[5]. Chain-based pelvic systems offer greater stability at the cost of bulk that may constrain joint mobility[5]. Custom-fitted jacket harnesses worn by rodents provide a naturalistic option[5], while the MARS centrifuge aboard the ISS remains the only true partial-gravity platform but is severely limited by cost and sample size[6]. Crucially, most of these systems were designed to study long-term musculoskeletal outcomes (bone density, muscle atrophy) rather than fine-grained locomotor kinematics, and none has been used to ask whether quadrupeds adopt a skip-like gait

under hypogravity.

Here we use a custom lightweight harness system to simulate lunar gravity in freely running mice on a treadmill. We first determine the anteroposterior center of mass position to validate harness placement, then characterise the resulting locomotor phenotype using markerless motion capture and a comprehensive kinematic analysis. We show that mice exposed to simulated lunar gravity spontaneously display a gait reorganisation with multiple features of human skipping: extended bilateral aerial phases, loss of hindlimb antiphase coupling, increased stride irregularity, and greater hindlimb clearance. These results provide the first evidence that a skip-like gait is not unique to bipeds but is an emergent locomotor response to reduced gravity that also manifests in quadrupeds.

2. Materials and Methods

Animals. All experiments were performed on adult mice of the PV^{cre};$Rx3^{flpo}$;$Mapt^{\mathrm{dsDTR}}$;Ai65D genotype. At the time of the locomotion recordings (day 0), no diphtheria toxin had been administered and animals exhibited a fully wild-type locomotor phenotype[7]. Eight mice were used for the center of mass determination experiment and seven mice for the treadmill locomotion experiment, in which each animal was recorded in both the Earth and Moon conditions (within-subject design). All procedures were conducted in accordance with institutional animal care and use guidelines[7].

Center of mass determination. Following euthanasia, animals were positioned in a standardised running posture — one diagonal limb pair extended, the contralateral pair flexed — and maintained in this configuration during rigor mortis. Specimens were stored at −80 °C and handled in a cold room at 4 °C to limit tissue warming during analysis. Each frozen specimen was suspended from a fixed overhead anchor via the tail-base strap of the harness, which was clamped at successive positions along the dorsal strap at 0.5 cm intervals. At each position, the animal was allowed to reach static equilibrium and a photograph was taken (*Samsung Galaxy Z Flip 5*; 50 cm fixed distance; 2× zoom to reduce peripheral distortion). Images were analysed in *Fiji* (*ImageJ* v1.54p): a reference segment was drawn along the body long axis and a perpendicular from the suspension point onto this reference; the tilt angle and the normalised suspension position were recorded. The anteroposterior CoM was estimated by linear regression restricted to the central portion of the curve ($0.35 \leqslant x \leqslant 0.70$ of normalised body length), and the zero-crossing of the fitted line was taken as the CoM position. A mass-based lookup table was derived by regressing body length against body mass.

Locomotion experiment. Mice ran on a motorised treadmill at 30 cm · s^{-1} wearing a custom suspension harness consisting of a commercially available soft Velcro jacket (*Butterfly Mouse Harness*, Lomir Biomedical Inc., Notre-Dame-de-l'Île-Perrot, QC, Canada) connected via a dorsal midline strap to a tail-base wrap, with a solid silicone elastic cord (*HokoFLEX*®, 1 mm nominal diameter, 60 Shore · A; HOKOSIL® Elastomertechnik GmbH, Bredenbek, Germany) providing vertical suspension[7]. In the Earth condition, the elastic element was slack. In the Moon condition, the cord was pre-tensioned to exert an upward force equal to 83.5% of body weight, reducing effective gravity to approximately $g_{\mathrm{Moon}} = 16.5\%\, g_{\mathrm{Earth}}$. Full-body kinematics were captured at 250 Hz using lateral high-speed cameras and processed with *DeepLabCut v2.3.9*[8] to extract anatomical landmarks including toe tips, metatarsal joints, knee, hip, iliac crest, scapula, and tail base.

Center of mass reconstruction and energy analysis. The whole-body CoM was approximated as the centroid of three landmarks (tail base, right iliac crest, and scapula), low-pass filtered at 10 Hz (zero-phase Butterworth, order 4)[9]. All other kinematic signals (joint angles, toetip and metatarsal trajectories) were filtered at 20 Hz with the same filter design. Velocity and acceleration were obtained by numerical differentiation[10]. The dominant oscillation frequency was identified as the spectral peak in the 1.5 Hz to 20 Hz band of the Welch power spectral density of the vertical CoM position. Effective gravity was estimated as the mean absolute vertical acceleration of the CoM during aerial phases (all four paws simultaneously off the ground), retaining only phases that contained at least one acceleration minimum to exclude spuriously brief events. The energy recovery ratio ER was computed following Cavagna et al.[11] as

$$ER = \frac{\Delta E_p + \Delta E_k - \Delta E_{\mathrm{tot}}}{\Delta E_p + \Delta E_k} \tag{1}$$

where $E_p = mgy_{\mathrm{CoM}}$ is the gravitational potential energy, $E_k = \frac{1}{2}m(v_x^2 + v_y^2)$ the kinetic energy of the CoM, $E_{\mathrm{tot}} = E_p + E_k$ the total mechanical energy, and $\Delta X = \sum \max(\Delta X_i, 0)$ denotes the sum of positive increments of quantity X over one stride.

Gait cycle analysis. Touchdown and liftoff events were extracted from the vertical toetip trajectories. The right hindlimb served as the gait-cycle reference; inter-limb phases were defined as the normalised timing of each limb's first touchdown within the reference cycle window. Circular statistics (mean direction and Rayleigh concentration $\bar{r}$) were computed analytically[12]. The Consecutive Cycle Irregularity was computed as

$$\mathrm{CCI} = \frac{\langle\, |T_{n+1} - T_n| \,\rangle}{\langle T \rangle} \tag{2}$$

where T_n is the duration of the n-th stride cycle, $\langle\cdot\rangle$ denotes the mean over all strides, and $|\cdot|$ the absolute

value. A high CCI indicates strongly alternating long and short strides, as expected during skipping.

Paw lift was computed as the time-integral of hindlimb toetip clearance above its swing-phase minimum, normalised by hindlimb length:

$$\text{Paw Lift} = \frac{1}{L_{\text{leg}}} \int_{t_{\text{lo}}}^{t_{\text{td}}} \left(y_{\text{toe}}(t) - y_{\text{min}}^{\text{sw}} \right) dt \qquad (3)$$

where t_{lo} and t_{td} are the liftoff and subsequent touchdown times of the hindlimb, $y_{\text{toe}}(t)$ is the vertical toetip position, $y_{\text{min}}^{\text{sw}} = \min_t y_{\text{toe}}(t)$ its minimum during the swing phase, and $L_{\text{leg}} = L_{\text{femur}} + L_{\text{tibia}}$.

Multivariate analysis. For each lower-limb joint (hip, knee, ankle, MTP), the joint angle per stride was normalised to $[0, 1]$ within each recording; four statistics were extracted from the resulting Poincaré return map: short-axis SD SD_1 (consecutive-cycle angle variability), long-axis SD SD_2 (overall angle variability), and the mean current-cycle and next-cycle normalised angles, yielding 16 stride-regularity parameters in total[13]. 104 locomotor parameters grouped into eight variable families were submitted to Multiple Factor Analysis[14, 15]. The significance of condition separation was assessed by PERMANOVA[16, 17] on Euclidean distances in MFA space (999 permutations). Univariate comparisons used linear mixed models with mouse as a random intercept; p-values were corrected by the Benjamini–Hochberg procedure.

Statistics. Unless otherwise stated, group comparisons used linear mixed-effects models with mouse identity as a random intercept, fitted by maximum likelihood[18], with Holm-corrected post-hoc pairwise contrasts[19]. Circular data were compared with the Watson-Williams test[12] applied to per-mouse mean phases. Bounded variables were logit-transformed prior to modelling. Effect sizes are reported as Cohen's d. All analyses were conducted in *R (v4.6.0)*.

3. Results

3.1 The center of mass of mice falls at mid-body and is insensitive to body mass

Effective hypogravity simulation requires that the elastic restoring force be applied directly above the animal's center of mass (CoM): any anteroposterior offset introduces a torque that tilts the body during locomotion. The harness used in this study (Fig. 1A) consists of a Velcro thoracic vest securing the forelimbs, linked by a dorsal midline strap to a tail-base wrap; the elastic element attaches to this strap at an adjustable anteroposterior position, providing a practical degree of freedom for CoM targeting.

To locate the CoM experimentally, we suspended frozen mice postured in a standardised running configuration from successive positions along the dorsal strap (Fig. 1B) and recorded the equilibrium tilt angle at each point. The zero-crossing, which locates the CoM, was remarkably consistent across animals and fell at 50.8% of total body length from the tail base (Fig. 1C). Body length scaled significantly with mass (Fig. 1D), allowing us to derive a lookup table that maps mass to expected CoM position (Fig. 1E). Over the full range of body masses encountered in the colony (18–30 g), the absolute CoM position changes by only 5 mm — confirming that a single standardised attachment suffices across animals.

3.2 The elastic harness produces a genuine hypogravity perturbation without perturbing stride mechanics

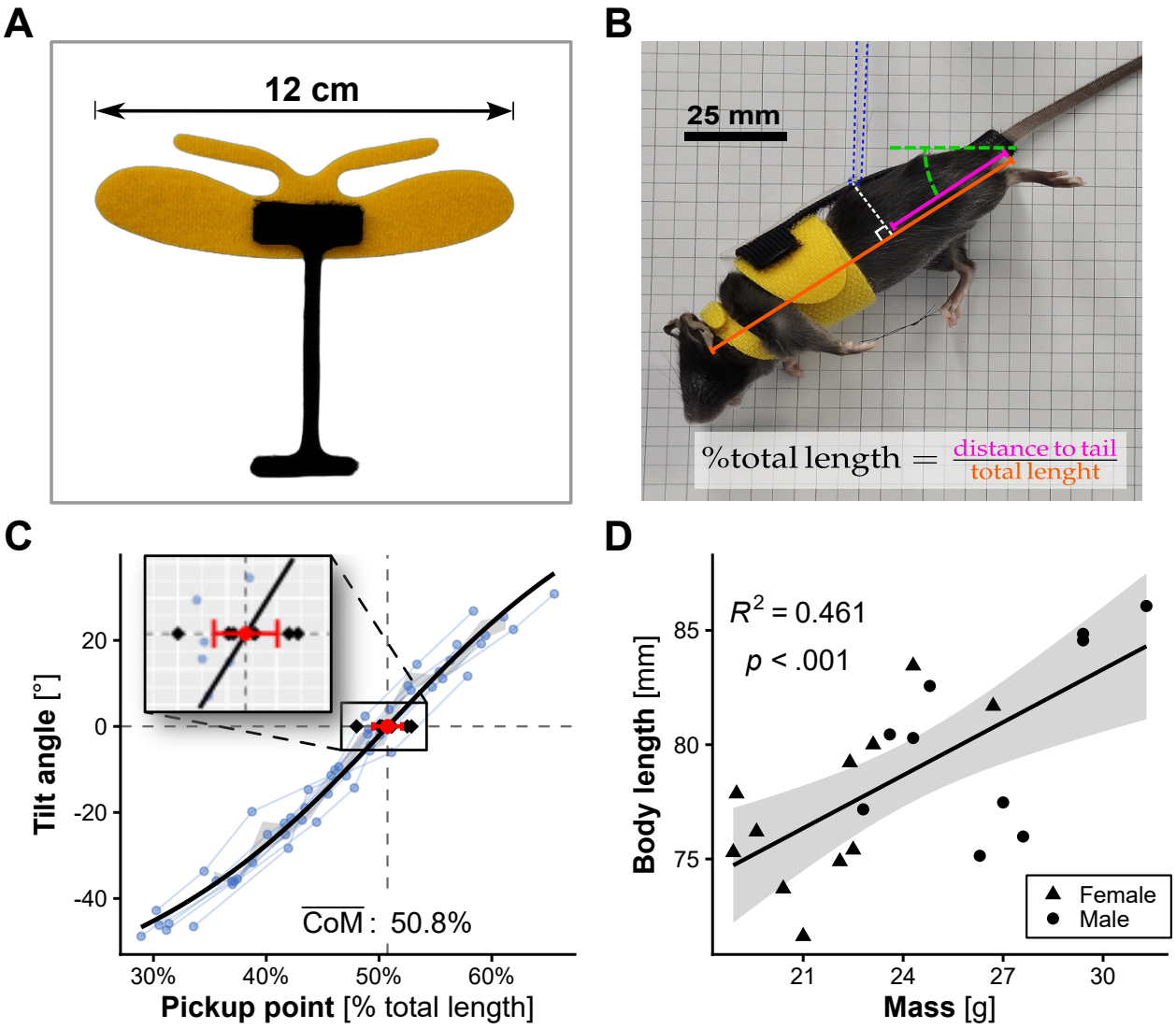
Seven mice were recorded on a treadmill at $30\,\text{cm} \cdot \text{s}^{-1}$ in two within-subject conditions: unsuspended (*Earth*) and suspended at 83.5% of body weight to simulate lunar gravity (*Moon*, $g_{\text{Moon}} \approx 16.5\%\, g_{\text{Earth}}$). The vertical CoM oscillated rhythmically at the stride frequency in both conditions (Fig. 2A); neither the peak-to-peak excursion, positional variability, nor dominant oscillation frequency differed significantly between conditions (Fig. 2B–D). The oscillation frequency was approximately 3.5 Hz in both conditions, consistent with the expected trot stride rate at this speed, and well above the theoretical resonance frequency of the suspension system ($f_0 = \frac{1}{2\pi}\sqrt{k/m} \approx 2.1\,\text{Hz}$, with cord stiffness $k \approx 4.3\,\text{N} \cdot \text{m}^{-1}$ and mouse mass $m \approx 25\,\text{g}$). Moon-suspended mice showed a significantly higher energy recovery ratio ER than Earth controls (Fig. 2G,H) — about two-thirds higher — indicating a shift toward pendular energy exchange under hypogravity[1].

3.3 Simulated lunar gravity disrupts inter-limb coordination

To characterise gait at the level of individual limb timing, we tracked all four paws during locomotion (Fig. 3A) and quantified inter-limb phases using the right hindlimb (RH) as the reference. Under simulated lunar gravity, the mean inter-limb phase shifted significantly for all three couplings relative to Earth controls, as assessed by the Watson-Williams circular test applied per mouse (Fig. 3D). Phase consistency, measured by the Rayleigh concentration $\bar{r}$, was significantly reduced for all three couplings under hypogravity (Fig. 3E). The hindlimb coupling dropped most severely — falling to less than half its Earth value under Moon conditions — indicating a profound loss of left-right hindlimb synchrony.

3.4 Skip-like kinematic signatures are significantly elevated under hypogravity

Five independent kinematic metrics were elevated under hypogravity (Fig. 4). The bilateral aerial time was 2.5-fold greater in Moon-suspended mice (7.0% of stride cycle; Fig. 4A). The Consecutive Cycle Irregularity (CCI; Eq. 2) was nearly twice as high in Moon-



E

Mass [g]	Total Length [mm]	Center of Mass [mm]
18	74 ± 2.8	37.6 ± 1.4
22	77.1 ± 1.6	39.1 ± 0.8
26	80.2 ± 1.6	40.7 ± 0.8
30	83.3 ± 2.7	42.3 ± 1.4

Figure 1. The center of mass of mice falls reproducibly at mid-body. (**A**) The custom suspension harness, consisting of a Velcro thoracic vest attached to a tail-base wrap by a dorsal midline strap. (**B**) Sagittal view of a mouse in a running posture suspended from the dorsal strap; the tilt angle and normalised pickup position are indicated. (**C**) Equilibrium tilt angle *vs.* normalised pickup-point position ($n = 8$ animals); the zero-crossing at $\overline{\text{CoM}} = 50.8\%$ of body length identifies the center of mass. (**D**) Body length *vs.* body mass (linear regression: $R^2 = 0.461$, $p < 0.001$; $n = 24$ animals). (**E**) Lookup table relating body mass to predicted CoM distance from the tail base (mean ± SD). Over the full mass range, the CoM position shifts by only 5 mm.

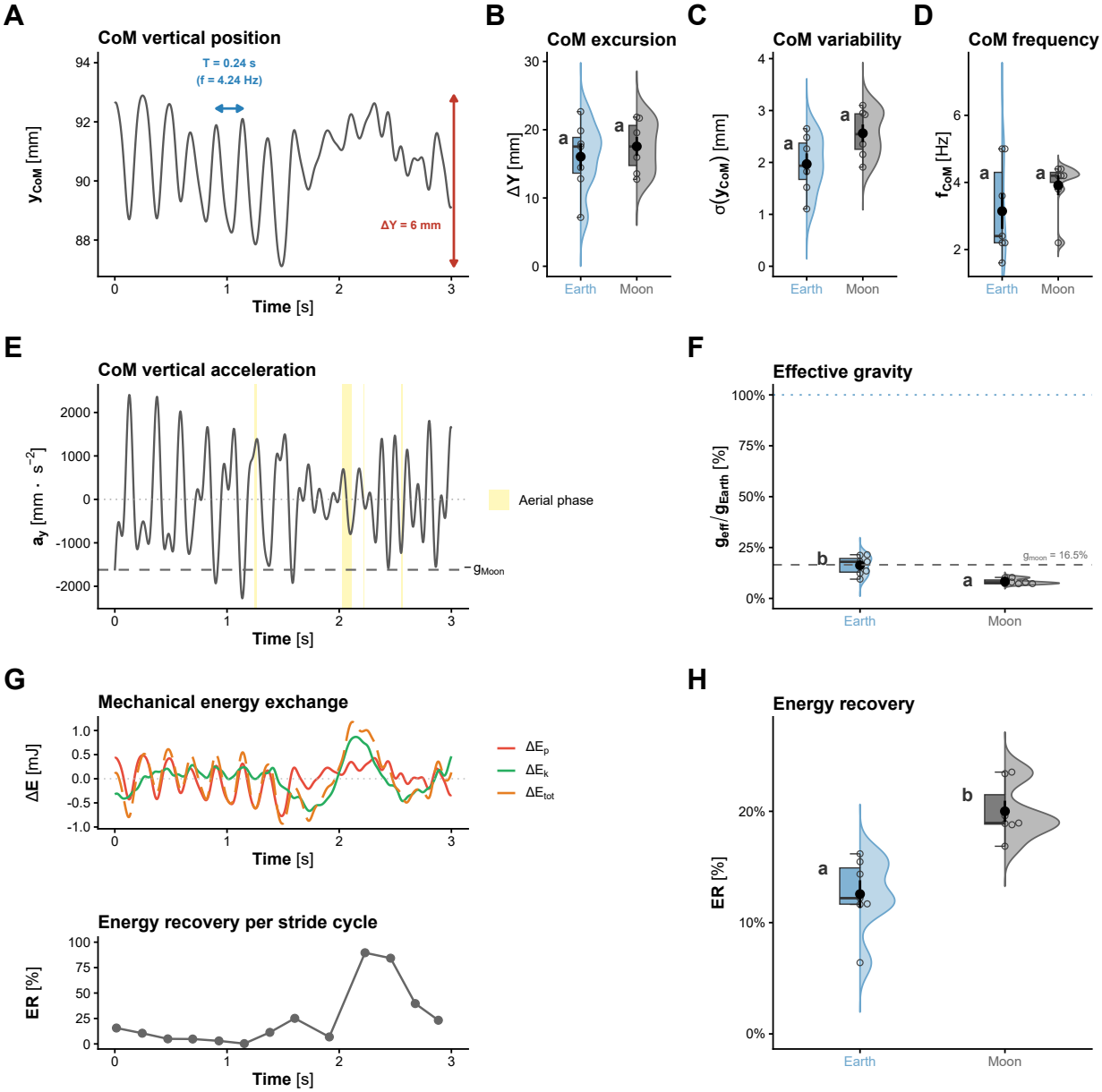


Figure 2. The elastic harness does not contaminate stride dynamics, yet reliably induces a hypogravity perturbation. (**A**) Representative vertical CoM position trace from a Moon-suspended mouse. (**B–D**) Group statistics for peak-to-peak excursion, positional variability, and dominant CoM frequency ($n = 7$); none differed significantly. In all group-comparison panels: right half shows a kernel-density estimate (violin); left half shows a boxplot (median, IQR, whiskers); open circles are individual mice; filled circle and error bar are mean ± SE. (**E**) Vertical CoM acceleration trace; yellow shading marks aerial phases. (**F**) Effective gravity $g_{\text{eff}}/g_{\text{Earth}}$ during aerial phases ($n = 7$); Moon-suspended mice experienced significantly lower effective gravity (linear mixed-effects model, Holm-corrected; $p < 0.05$). (**G**) Representative energy exchange trace. (**H**) Energy recovery ratio ER ($n = 7$); Moon-suspended mice showed significantly higher ER (linear mixed-effects model, logit-transformed, Holm-corrected; $p < 0.05$). Different letters: significant post-hoc differences ($\alpha = 0.05$).

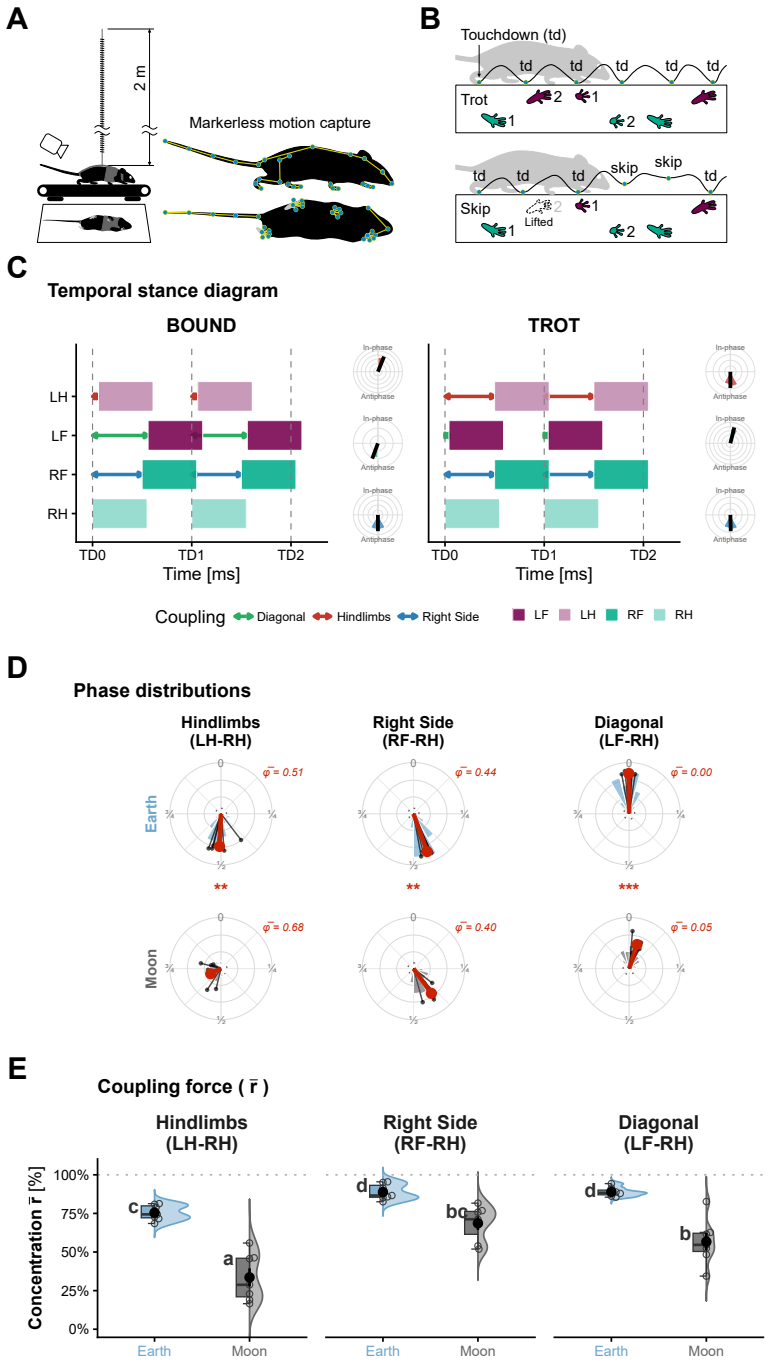


Figure 3. Simulated lunar gravity disrupts inter-limb coordination. (**A**) Experimental setup: mice ran at $30\,\mathrm{cm}\cdot\mathrm{s}^{-1}$ under Earth or Moon gravity while high-speed cameras recorded full-body kinematics[7]. (**B**) Schematic illustrating the skip-like gait pattern: a regular trot (top) is replaced by a long-short stride alternation (bottom) when hindlimb phase coupling is disrupted[7]. (**C**) Temporal stance diagrams for trot and bound reference gaits. (**D**) Inter-limb phase polar plots for three pairwise couplings under Earth (top) and Moon (bottom) ($n = 7$). (**E**) Rayleigh concentration $\bar{r}$ for all three couplings ($n = 7$). All three were significantly reduced under hypogravity (linear mixed-effects model, logit-transformed, Holm-corrected). Different letters: significant post-hoc differences ($\alpha = 0.05$).

Table 1. The eight variable families submitted to MFA (n = number of parameters per family).

Family	n	Parameters
TEMPORAL	28	Per-limb cadence, stance and swing duration (mean, SD, CV), and duty factor for all four limbs (Fig. 5)
COORDINATION	7	Inter-limb phases $\bar{\phi}$, Rayleigh concentration $\bar{r}$, bilateral aerial time, and swing asymmetry (Fig. 3, Fig. 4)
TRAJECTORIES	30	Per-limb step height, stride length, and paw lift (mean and SD); stride-length ataxia coefficient; tail-base height (Fig. 4, Fig. 5)
POINCARÉ	16	Stride-to-stride joint angle consistency via Poincaré return maps for each lower-limb segment (Fig. 5)
KINEMATICS	12	Minimum, maximum, and range of motion of the hip, knee, ankle, and MTP joints (Fig. 5)
BASE OF SUPPORT	3	Maximum, minimum, and range of convex-hull stance area across stride cycles (Fig. 4)
COM DYNAMICS	5	ΔY, $\sigma(y_{\mathrm{CoM}})$, f_{CoM}, g_{eff}, and ER (Fig. 2)
MORPHOMETRY	3	Body mass, femur length, and tibia length

suspended mice (32.4%; Fig. 4D). Normalised paw lift (Fig. 4E) was threefold greater under hypogravity, and base of support (Fig. 4F) was also threefold larger. A composite skip score aggregating nine kinematic variables drawn from Figs. 2 to 4 — each min-max normalised to $[0, 1]$ across all animals and conditions — was significantly higher in Moon-suspended mice (Fig. 4G).

3.5 An unbiased multivariate analysis reveals a global locomotor reorganisation

All preceding analyses targeted pre-selected variables. To ask without prior hypothesis whether the Earth-Moon difference was confined to these variables or reflected a global reorganisation, we performed a Multiple Factor Analysis (MFA[14]) on 104 locomotor parameters grouped into eight families (Table 1).

Dimension 1 captured 46.2% of total variance and Dimension 2 an additional 17%, together accounting for 63.2% of all locomotor variability. PERMANOVA confirmed significant overall separation between groups ($R^2 = 0.638$, $p = 0.001$), indicating that 63.8% of all locomotor variability is attributable to whether the mouse ran on Earth or the Moon. Unbiased k-means clustering ($k = 2$) perfectly recovered the Earth and Moon groups without access to experimental labels. Of the 104 parameters tested, 75 were significantly different between conditions (Fig. 5C).

4. Discussion

The central finding of this study is that mice exposed to simulated lunar gravity spontaneously express a gait reorganisation with multiple features of the skipping observed in human astronauts under the same gravitational condition. Under hypogravity, mice displayed doubled stride irregularity, threefold increases in paw lift and base of support, elevated energy recovery, and a global loss of inter-limb phase coordination — changes captured without prior hypothesis by an unbiased multivariate analysis separating the two conditions with an R^2 of 0.638. To our knowledge, this is the first demonstration that a skip-like gait emerges in a quadrupedal species under reduced gravity.

Similarities and differences with human lunar skipping. In humans, skipping under hypogravity is characterised by a persistent leading-limb asymmetry alongside increased stride irregularity and greater foot clearance[2, 3]. Our data reproduce the irregular stride timing and increased paw clearance faithfully, but left-right hindlimb swing asymmetry did not reach significance in mice. This likely reflects a fundamental difference between bipedal and quadrupedal locomotion: in a biped, skipping requires a committed choice of leading limb, whereas a quadruped may distribute the asymmetry across both sides, diluting the signal at the group level.

More broadly, the gravitational reduction renders energetics a poor predictor of gait choice: on the Moon, the metabolic costs of running, skipping, and hopping converge to near-Earth-walking values[3, 20], even though hopping is prohibitively expensive on Earth. This metabolic equivalence implies that the gait repertoire in hypogravity is shaped primarily by biomechanical constraints and neuromechanical timescales.

Comparison of hypogravity simulation modalities. The elastic suspension system used here belongs to a family of partial weight-bearing (PWB) devices, each presenting a distinct trade-off between mechanical fidelity, practicality, and impact on natural movement[5]. The custom Velcro-and-elastic harness used here is lightweight, minimally obstructive, and allows unrestricted quadrupedal locomotion without daily recalibration. Its main drawbacks are: Velcro degrades after approximately five to six experimental sessions; and the single-point overhead attachment provides no lateral stability. A neoprene construction and a triangular suspension geometry would address both limitations.

Limitations. A systematic underestimation of g_{eff} relative to theoretical predictions was observed in both conditions, a recognised limitation of reconstructing CoM dynamics from surface-landmark tracking during fast locomotion[21]. Because this bias affects both conditions equally, the statistically robust Earth-Moon difference in g_{eff} remains a valid indicator of the relative change in gravitational loading.

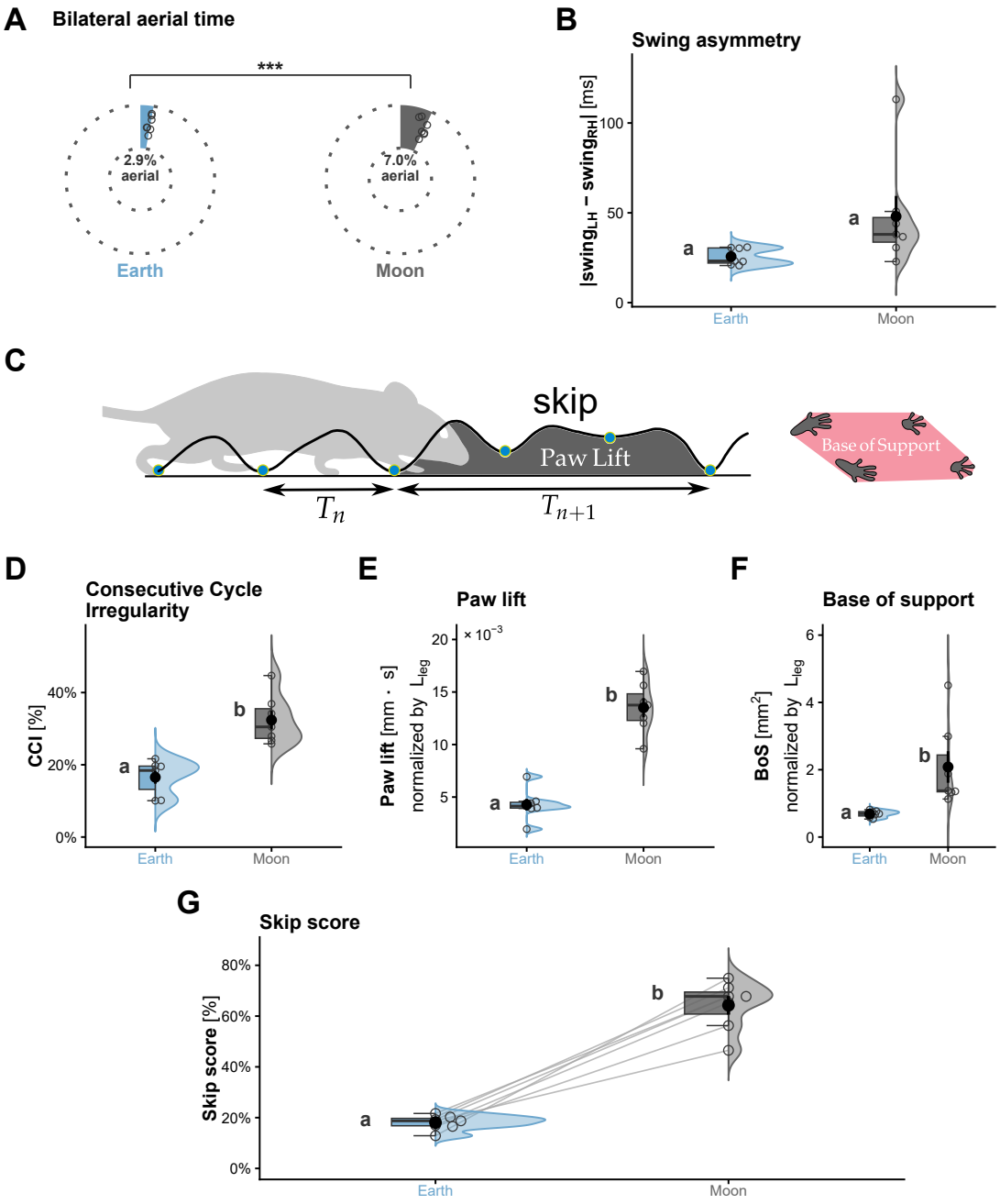


Figure 4. Skip-like kinematic metrics are all significantly elevated under hypogravity. (**A**) Bilateral aerial time ($n = 7$). Individual mouse values are shown as dots; the donut chart arc represents the group mean. Significantly elevated under hypogravity (linear mixed-effects model, Holm-corrected; $p < 0.001$). (**B**) Left-right hindlimb swing asymmetry ($n = 7$); not significantly different between conditions. (**C**) Schematic illustrating CCI, paw lift, and base of support (BoS). (**D**) CCI, (**E**) paw lift, and (**F**) BoS ($n = 7$); all significantly elevated under hypogravity (Holm-corrected; $p < 0.05$). (**G**) Composite skip score ($n = 7$); significantly higher in Moon-suspended mice (logit-transformed, Holm-corrected). Different letters: significant post-hoc differences ($\alpha = 0.05$).

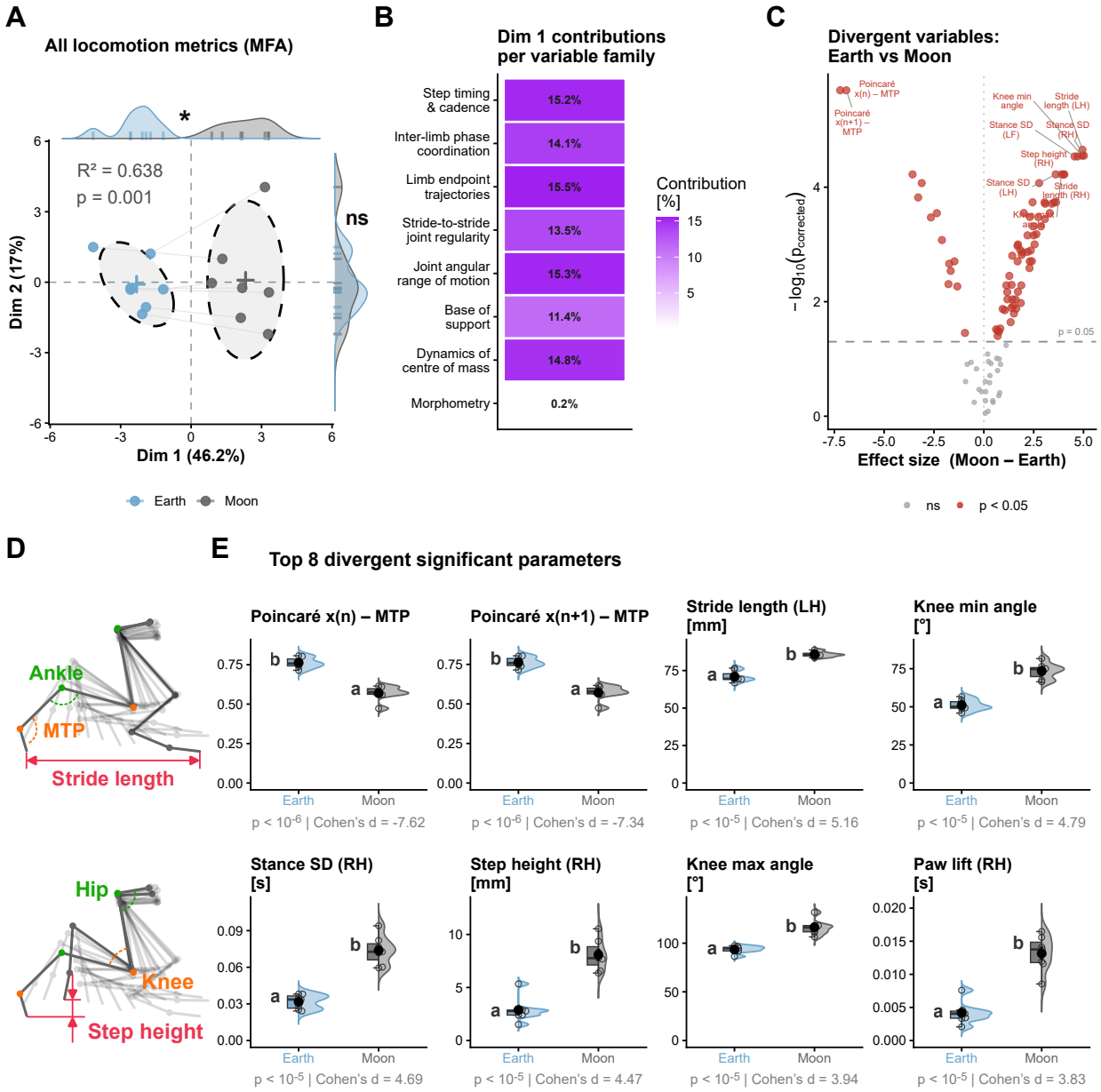


Figure 5. An unbiased multivariate approach shows that locomotion under simulated hypogravity is globally and specifically altered. (**A**) MFA of 104 locomotor parameters projected onto Dimensions 1 and 2; individual recordings are coloured by condition (Earth, blue; Moon, grey). Ellipses delineate the two k-means clusters. PERMANOVA: $R^2 = 0.638$, $F_{1,12} = 21.16$, $p = 0.001$. (**B**) Contribution of each variable family to Dimension 1; all locomotor families contributed equally (11–16%), while morphometry contributed only 0.2% (negative control). (**C**) Volcano plot of effect size (Moon − Earth, Cohen's d) against corrected $-\log_{10}(p)$ for all 104 parameters. Points in red are significant after Benjamini–Hochberg correction; 75 out of 104 parameters were significantly different. (**D**) Hindlimb joint schematic. (**E**) Group comparison plots ($n = 7$) for the eight parameters with the largest significant effect sizes. Different letters: significant post-hoc differences ($\alpha = 0.05$, linear mixed-effects model, Holm-corrected).

Perspectives. The present dataset characterises the immediate, neuromechanically intact response to hypogravity at day 0. The animals used here carry genetic tools for inducible selective ablation of specific neuronal populations, making it possible to ask which spinal circuits are required for the gravity-dependent gait reorganisation[7]. A longitudinal design would also reveal whether the skip-like pattern is a stable attractor or a transient response — a question with direct implications for predicting long-term locomotor adaptation during future lunar surface missions.

Author Contributions

A.M. performed all data analysis and statistical analyses, prepared all figures, and collected and analysed the center-of-mass suspension data. N.Z. supervised the project and reviewed and edited the manuscript. A.S. recorded the treadmill videos, performed markerless pose estimation, and assembled the landmark coordinate dataset[7].

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