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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐ A description of all covariates tested
☒	☐ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☐	☒ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Biplanar X-ray videos were analyzed using XMALab (v.1.5.5). Tracked marker 3D coordinates were imported to Autodesk Maya (v.2020) and animations were derived using XROMM Maya Tools (v.2.2.3). Animated trials were used to drive DEM simulations in LIGGGHTS (v.3.8.0), which were subsequently visualized using OVITO (v.3.0.0).
Data analysis	Autodesk Maya (v.2020) and OVITO (v.3.0.0) were used to analyze track formation dynamics. R (v.4.1.0) was used to generate plots, and scripts included functions from the dplyr (v.1.0.7) and ggplot2 (v.3.3.5) packages.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All processed data that led to the conclusions of this study are available in the main text or the supplementary materials. Source data and code used to generate the figures in this manuscript are publicly available at the following address: https://doi.org/10.6084/m9.figshare.20736697. Raw data are publicly available through the XMAPortal at the following link: https://xmaportal.org/webportal/larequest.php?request=CollectionView&StudyID=43&instit=BROWN&collectionID=20.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	The study involved biplanar X-ray experiments aimed at understanding how arched footprints are formed when humans walk on deformable substrates. Mechanistic processes observed in these experiments were deciphered using 3-D animation and discrete element particle simulation. Experimental footprints were then compared with fossil hominin footprints, and with footprints created by chimpanzees, to understand whether those record similar patterns of foot mechanics.
Research sample	The experimental research sample included eight young adults (7 female, 1 male, all in their early to mid-twenties). Each subject's feet were recorded via biplanar X-ray video as they walked a minimum of three times across each of four substrates (rigid carbon fiber, "firm" mud, "wet 2.5" mud, "wet 5" mud). In trials where subjects produced footprints, these were digitized using photogrammetry or a structured light 3-D scanner. Experimental chimpanzee tracks, and the Laetoli G1 tracks, were digitized by K.G.H. using photogrammetry, as part of a previously published study (Hatala et al., 2016). Laetoli S1 and A tracks were accessed through Morphosource (www.morphosource.org). Ileret tracks were also digitized by K.G.H. using photogrammetry, following their excavation as part of an earlier study (Hatala et al., 2017). Models of Walvis Bay tracks were made freely available online by Professor Matthew Bennett through NERC grant NE/HOO4211/1 (http://footprints.bournemouth.ac.uk/) and have been described by Morse et al. (2013). Analyses also included experimental human footprints collected in a previously published study (Hatala et al., 2016); that sample included 69 footprints made by 24 subjects, ranging widely in age from children to adults (ages 4-47).
Sampling strategy	Experimental sample size was determined by the feasibility of data processing and by the clarity of observations of track formation processes. Biplanar imaging and particle simulation are immensely time-consuming, such that large sample sizes are impractical. Here, the clarity of the observed patterns of arch formation did not necessitate additional data collection. Sample sizes of fossil hominin tracks were determined based on data availability and the nature of track preservation - as many tracks as possible were included for each of the samples analyzed.
Data collection	Biplanar X-ray experiments were conducted, and videos were digitized and animated, by K.G.H. and S.M.G. Discrete element particle simulations were conducted by P.L.F. Both K.G.H. and P.L.F. measured experimental tracks in order to assess interobserver error. Fossil hominin tracks were measured by K.G.H.
Timing and spatial scale	Biplanar X-ray experiments were conducted from June 25-28, 2019. A second set of experimental data, which was included in only a single analysis (Fig. 4), was collected from July 26-29, 2021.
Data exclusions	Some fossil hominin tracks were excluded from the analyses shown in Figure 4, and some experimental tracks were excluded from Extended Data Figure 1. Because our experiments (and others) show that track arch morphology is influenced by track depth, we restrict our arch comparisons to tracks of similar depth. Tracks were included in Figure 4 and Extended Data Figure 1 only if their absolute depths were within two standard deviations of the mean depths observed in deep mud tracks from our human experiments.
Reproducibility	All data analyzed here are made publicly available, and the methods used to analyze them are described in detail. We did evaluate interobserver error in measurements of track and foot arches (Extended Data Fig. 5), and found interobserver differences to have minimal impact on results.
Randomization	Randomization was not relevant to our study because we were interested in understanding the mechanistic processes that led to specific patterns of track development, and in inter-group comparisons of footprint samples.
Blinding	Blinding was not relevant to our study, as human subjects had no prior knowledge of our plans to study the mechanics of track arch formation.

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☐	☒ Palaeontology and archaeology
☒	☐ Animals and other organisms
☐	☒ Human research participants
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Palaeontology and Archaeology

Specimen provenance	No new fossils were excavated or collected for this study. All material analyzed here has been published previously.
Specimen deposition	The specimens measured here have been published previously and details on availability are provided in those original publications.
Dating methods	No new dates are provided here.

☐ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.

Ethics oversight	Ethical oversight was not relevant here because the study only required access to previously published data.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Human research participants

Policy information about studies involving human research participants

Population characteristics	Data were collected from 8 healthy young adults (7 female, 1 male, all in their early twenties), without any foot or lower limb maladies, or injury/surgical histories, that might impact their foot function. Due to the exposure to small amounts of X-ray radiation, subjects were also excluded if there was any chance of pregnancy.
Recruitment	Participants were recruited via e-mail. We did not identify any potential for recruitment bias that could impact results.
Ethics oversight	Ethical approval was provided by the Brown University and Chatham University Institutional Review Boards.

Note that full information on the approval of the study protocol must also be provided in the manuscript.