

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
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☒ | ☐ 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
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ 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

Data analysis

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](#)

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender

Use the terms *sex* (biological attribute) and *gender* (shaped by social and cultural circumstances) carefully in order to avoid confusing both terms. Indicate if findings apply to only one sex or gender; describe whether sex and gender were considered in study design; whether sex and/or gender was determined based on self-reporting or assigned and methods used. Provide in the source data disaggregated sex and gender data, where this information has been collected, and if consent has been obtained for sharing of individual-level data; provide overall numbers in this Reporting Summary. Please state if this information has not been collected. Report sex- and gender-based analyses where performed, justify reasons for lack of sex- and gender-based analysis.

Reporting on race, ethnicity, or other socially relevant groupings

Please specify the socially constructed or socially relevant categorization variable(s) used in your manuscript and explain why they were used. Please note that such variables should not be used as proxies for other socially constructed/relevant variables (for example, race or ethnicity should not be used as a proxy for socioeconomic status). Provide clear definitions of the relevant terms used, how they were provided (by the participants/respondents, the researchers, or third parties), and the method(s) used to classify people into the different categories (e.g. self-report, census or administrative data, social media data, etc.) Please provide details about how you controlled for confounding variables in your analyses.

Population characteristics

Describe the covariate-relevant population characteristics of the human research participants (e.g. age, genotypic information, past and current diagnosis and treatment categories). If you filled out the behavioural & social sciences study design questions and have nothing to add here, write "See above."

Recruitment

Describe how participants were recruited. Outline any potential self-selection bias or other biases that may be present and how these are likely to impact results.

Ethics oversight

Identify the organization(s) that approved the study protocol.

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

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](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Life sciences study design

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

Sample size

No sample size calculations were performed as no sampling of populations were performed in this study.

Data exclusions

No data were excluded from the analysis. All collected data were included, and no exclusion criteria were pre-established.

Replication

Experiments were replicated at least three times in independent setting, all attempts replication were successful.

Randomization

For data generation in biological experiments, samples were spatially randomly distributed in the various replicates.

Blinding

Blinding was not relevant as these experiments were not a case-controlled study.

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
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

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

Antibodies

Antibodies used

Rabbit anti-PDI antibody, Abclonal, Cat#A19239
 Mouse anti-Erp5 antibody, Santa Cruz, Cat#sc-365260
 Rabbit anti-Erp57 antibody, Wang, L. et al. Platelet-derived Erp57 mediates platelet incorporation into a growing thrombus by regulation of the α IIb β 3 integrin. Blood 122, 3642-3650 (2013).
 Rabbit anti-ERP72 antibody, Abclonal, Cat#A4326
 Rabbit anti-P4HA1 antibody, ProteinTech, Cat#12658-1-AP
 Mouse anti-P4HA2 antibody, ProteinTech, Cat#66604-1-Ig
 Rabbit anti-P4HA3 antibody, ProteinTech, Cat#23185-1-AP
 Rabbit anti-Caspase 3 antibody, Abmart, Cat#T40044F
 Rabbit anti-Caspase 9 antibody, Abmart, Cat#T40046F
 Rabbit anti-Bcl-2 antibody, Abmart, Cat#T40056F
 Rabbit anti-Bip antibody, Abmart, Cat#P23089-2F
 Rabbit anti-PERK antibody, Abmart, Cat#TP52759F
 Rabbit anti-p-elf2 α antibody, Cell Signaling Technology, Cat#3597S
 Mouse anti-GAPDH antibody, Cell Signaling Technology, Cat#60004-1-Ig

Validation

Antibodies generated in this study were validated by the manufacturer using western blots. The experimenters also validated the antibodies with western blot experiments that are present in the manuscript.

Animals and other research organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research, and [Sex and Gender in Research](#)

Laboratory animals

The PDlfl/fl mice were generated by the International Knockout Mouse Consortium (IKMC) at the Cambridge-Suda Genomic Resource Center. This was accomplished using embryonic stem cells harboring a floxed PDI gene (clone number: EPD0317_6_D10). The targeting vector included loxP sites positioned between exons 2 and 3, and between the fourth loxP site and exon 5 of the PDI gene. This vector was subsequently introduced into fertilized mouse oocytes to facilitate endogenous integration. The recombination between the two FRT sites was achieved by expression of Flp recombinase under the control of the β -actin promoter. For osteoblast-specific PDI gene knockout, PDlfl/fl mice were crossed with Osx-Cre transgenic mice obtained from The Jackson Laboratory. This mating strategy facilitated the excision of exons 3 and 4 by recombination between the two loxP sites, thereby resulting in the deletion of the PDI gene.

All experiments involving mice were conducted in strict accordance with institutional guidelines and were approved by the Institutional Animal Care and Use Committee of Soochow University. The overall development and health of the animals were monitored following the guidelines set forth by the Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC). Mice were housed in a specific pathogen-free (SPF) facility at Soochow University, maintained on a 12-hour light/dark cycle, with temperature controlled at $24 \pm 2^\circ\text{C}$ and humidity maintained at $55 \pm 5\%$.

Wild animals

This study did not involve wild animals.

Reporting on sex

Given the differences in bone development between male and female mice, and the potential impact of these differences on bone development, only male mice were used in this study.

Field-collected samples

This study did not involve samples collected from the field.

Ethics oversight

Experiments with mice were performed in accordance with institutional guidelines and with the approval of the Institutional Animal Care and Use Committees of Soochow University (Suzhou, China).

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

Plants

Seed stocks	Report on the source of all seed stocks or other plant material used. If applicable, state the seed stock centre and catalogue number. If plant specimens were collected from the field, describe the collection location, date and sampling procedures.
Novel plant genotypes	Describe the methods by which all novel plant genotypes were produced. This includes those generated by transgenic approaches, gene editing, chemical/radiation-based mutagenesis and hybridization. For transgenic lines, describe the transformation method, the number of independent lines analyzed and the generation upon which experiments were performed. For gene-edited lines, describe the editor used, the endogenous sequence targeted for editing, the targeting guide RNA sequence (if applicable) and how the editor was applied.
Authentication	Describe any authentication procedures for each seed stock used or novel genotype generated. Describe any experiments used to assess the effect of a mutation and, where applicable, how potential secondary effects (e.g. second site T-DNA insertions, mosaicism, off-target gene editing) were examined.