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Last updated by author(s): Aug 3, 2020

Reporting Summary

Nature Research 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 Research 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	ESPRIT 2 for stitching SEM and EDX images. Adobe Photoshop CS6 for image processing. Microsoft Excel 2019 MSO 32 for coding phylogenetic matrices.
Data analysis	MrBayes v.3.2.7a x64 and TNT v.1.5 for phylogenetic analysis. Code is provided along with the phylogenetic datasets in the NEXUS format files as Supplementary Data 1 and 2.

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 Research 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 list of figures that have associated raw data
- A description of any restrictions on data availability

All data analysed in this paper, including the phylogenetic datasets, are available as part of the Article, Extended Data Figs. 1–10 or Supplementary Information. The nomenclatural acts in this publication have been registered at ZooBank (LSID: urn:lsid:zoobank.org:pub:3B79BB94-239D-4C0A-93E5-62E90DAE6469).

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	This study is a palaeontological investigation involving collection, description, comparison and phylogenetic analyses of fossil material from the lower Cambrian of Yunnan, China.
Research sample	Our sample includes all of the six specimens of Kylinxia zhangi gen. et sp. nov. found at the Jianshan section (NIGP 171304–171308, YLSNHM 01124) . Sources of specimens of other fossil taxa used as comparisons in this study are listed with details in the Methods.
Sampling strategy	All fossils of the same type encountered during the excavation were collected.
Data collection	Fangchen Zhao led the fossil excavation at the Jianshan section and discovered NIGP 171304–171308, in which Yehui Zhang and Kecheng Niu participated and found YLSNHM 01124. NIGP 171304–171312 are deposited at the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China. YLSNHM 01124 is housed at the Yingliang Stone Natural History Museum, Nan'an, China.
Timing and spatial scale	Collection of the fossil specimens at the Jianshan section began in 2017 and is ongoing. All the specimens of K. zhangi described were collected from the Maotianshan Shale Member, Yu'anshan Formation (Cambrian Series 2, Stage 3, Wutingapsis-Eoredlichia Biozone) at the Jianshan section, Haikou, Kunming, China. The timing scale was verified by the index trilobite fossil Eoredlichia. The spatial scale was well-justified by the comprehensive geological studies in the area.
Data exclusions	No data exclusions.
Reproducibility	All new fossil specimens will become available upon publication.
Randomization	No data randomization because no related analyses were conducted in this study.
Blinding	No blinding because no biological experiments were performed in this study.

Did the study involve field work? ☒ Yes ☐ No

Field work, collection and transport

Field conditions	Slabs of fossil specimens were excavated manually from well-exposed outcrops of fossiliferous claystone. The fossiliferous claystone has been weathered under a warm and humid climate with an average temperature of 15.7 Celsius and an average amount of rainfall of 965.8 mm per year.
Location	Jianshan section, Haikou, Kunming, China. Latitude: N24°46'17.23''. Longitude: E102°35'10.2''. Elevation: 1950 m.
Access & import/export	New fossil specimens in this study were collected by the field parties led by the Nanjing Institute of Geology and Palaeontology in compliance with the local, national and international laws. The permissions of excavation were obtained from the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences in January 2017.
Disturbance	Disturbance to the quarry sites was minimized by controlled excavation. Reclamation of the quarries will be carried out under the scheduled procedure of the local government.

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	NIGP 171304–171311 and YLSNHM 01124 were from the Jianshan section, Haikou, Kunming, Yunnan Province, China. Sources of specimens of other taxa used as comparisons in this study are listed with details in the Methods. The working permissions of excavation at the Jianshan section, with official certificate letters, were obtained from the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences in January 2017.
Specimen deposition	The new specimens NIGP 171304–171312 are deposited at the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China. YLSNHM 01124 is housed at the Yingliang Stone Natural History Museum, Nan'an, China. Sources of specimens of other taxa used as comparisons in this study are listed with details in the Methods.
Dating methods	No new dates are provided.

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

Ethics oversight	The Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences approved the study protocol.

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