nature portfolio

Corresponding author(s): Michael Garratt
Last updated by author(s): 02/10/25

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.

Please do not complete any field with "not applicable" or n/a. Refer to the help text for what text to use if an item is not relevant to your study.
For final submission: please carefully check your responses for accuracy; you will not be able to make changes later.

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: No software was used for data collection.

Data analysis: All code, data-sets and figures are displayed in the Supplementary Information HTML file, found at DOI 10.5281/zenodo.17333443. The following packages were used in the analysis: phytools(v.2.4-4), maps(v.3.4.3), ggtree(v.3.16.3), ggstance(v.0.3.7), ggimage(v.0.3.3), apextra(v.0.0.0.1), cowplot(v.1.2.0), ggalluvial(v.0.12.5), GoodmanKruskal(v.0.0.3), naniar(v.1.1.0), formatR(v.1.14), here(v.1.0.1), png(v.0.1-8), MuMIn(v.1.48.11), clubSandwich(v.0.6.1), orchaRd(v.2.0), rotl(v.3.1.0), emmeans(v.1.11.2), readxl(v.1.4.5), lme4(v.1.1-37), patchwork(v.1.3.1), kableExtra(v.1.4.0), ape(v.5.8-1), pander(v.0.6.6), metafor(v.4.8-0), numDeriv(v.2016.8-1.1), metadat(v.1.4-0), Matrix(v.1.7-3), lubridate(v.1.9.4), forcats(v.1.0.0), stringr(v.1.5.1), dplyr(v.1.1.4), purrr(v.1.1.0), readr(v.2.1.5), tidyr(v.1.3.1), tibble(v.3.3.0), ggplot2(v.3.5.2), BaSTA (v2.0.2) and tidyverse(v.2.0.0).

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 data needed to reproduce the conclusions is available at DOI 10.5281/zenodo.17333443. The extracted data from primary sources used in the meta-analyses is also included at these sites. Raw data used for survival analysis to estimate life expectancies and aging rates was from the ZIMS module of the Species360 database (Species360 Data Use Approval no. 98486) This data cannot be publicly shared, as Species360 is the custodian (not the owner) of their members' data. However, Raw data are accessible from Species360 through Research Request applications (form available at https://docs.google.com/forms/d/1znoy62VEkDlhAp_0RfEvF7Zsx03g4W5AlppJHqo3_WQ/viewform?edit_requested=true&pli=1).

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	NA
Reporting on race, ethnicity, or other socially relevant groupings	NA
Population characteristics	NA
Recruitment	NA
Ethics oversight	NA

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

Life sciences study design

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

Sample size

For the zoo data, we selected datasets for which we had at least 30 individuals per type of contraception, such that the total number of individuals (contracepted + non-contracepted) was at least 100. For the competing risk modelling we selected species for which there were at least 15 individuals with cause of death information in the contracepted category, for a minimum of 50 between contracepted and non-contracepted.
Sample sizes used were based on the minimum deemed required for sufficient estimation of the related effect sizes.

Data exclusions

For the zoo analysis, we removed any animals from data analysis that were recorded as “unknown” or “undetermined” contraception type within the ZIMs database. To calculate Risk Difference for cause of death data, we could only include data from species where at least one individual had died from that cause of death in both contracepted and non-contracepted animals. Excluding comparisons where no deaths had occurred in one group also prevented biases in RD calculations that could arise due to unequal samples between groups.
we had to exclude data from any species where no animals were excluded from any analysis. Each meta-analysis has predefined inclusion criteria for whether studies could be included in the analysis.
For the meta-analysis of changes in lifespan: (1) Studies must report the original empirical data from vertebrate animals, not reviews or computer simulations; (2) A permanent (i.e. surgical) or long-lasting sterilization must have been conducted that allowed survival to be assessed across this period and compared to a comparable non-treated animals (a control group/set of individuals within a population); (3) Survival must be assessed, either across lifespan (e.g. mean/median lifespan/survival curve) or a defined period of adulthood (e.g. proportion of individuals surviving the year following castration); (4) Animals used must be a wild-type species or strain, without purposely increased disease incidence (e.g. a cancer model) or genetic manipulation (although a control group’s data from a genetic manipulation/cancer study could be used); (5) Method of sterilization should not have other systemic effects that could influence lifespan (e.g. sterilization by radiation that increases cancer risk or somatic mutations); (6) Animals should not be treated with any other confounding factors, such as drugs, irradiation, or injection with pathogens; (7) Survival data should be reported according to sex and treatment group; and (8) The study should not be assessing survival rates/mortality that are incurred from the procedure itself (e.g. women that suffer mortality due to a problem with the surgical event of tubal ligation). Studies of the effect of sterilisation on survival in women were included if they met the following additional criteria: (1) The method of sterilisation was permanent (e.g. surgical sterilisation rather than birth control); (2) Sterilization was conducted for a benign condition; and (3) The effect of sterilisation could be compared to a non-sterilized (intact) control group.
For the meta-analysis of changes in healthspan: Animals must have been castrated or ovariectomized for an extended period from before the middle of life (for 6 months or more before testing, and the sterilization must have been conducted at or before the animal was 12 months old). Healthspan tests must have been conducted at some point beyond middle-age (in animals that are at least 12 months old) AND at least 6 months after the intervention. In addition, we included several other inclusion criteria that were concordant with the meta-analysis of changes in survival. (1) Studies must be the original empirical data using real laboratory rats (*Rattus norvegicus*) or mice (*Mus musculus domesticus*). The studies cannot be reviews, syntheses or computer simulations. (2) Animals used must be a wild-type species or strain, without purposely increased disease incidence (e.g. a cancer model) or genetic manipulation (although a control group’s data from a genetic manipulation/cancer study could be used). (3) Type of sterilization/castration intervention must be stated. We exclude all comparisons with “undetermined” contraception type. (4) Sterilization/castration intervention must have been conducted, and compared to, comparable non-treated animals (a control group/set of individuals within a population). (5) Method of sterilization shouldn’t have other systemic effects that could influence lifespan (e.g. sterilization by radiation that increases cancer risk or somatic mutations). (6) Animals should not be treated with any other confounding factors, such as drugs, irradiation or injection with pathogens. (7) Healthspan must be assessed for at least one of the outcomes recommended in Richardson et al. (2016), Bellantuono et al (2020), Pettan-Brewer et al (2011 - pathology outcomes) or Snyder et al (2019 - pathology outcomes). See Supplementary Table 7 for the eligible outcomes. (8) Healthspan data must be reported according to sex. We excluded all evidence with unknown or mixed-sex of the animals. (9) Healthspan outcome measures must be quantified and reported in a form that allows calculation of the effect size, which can be interpreted as directional differences in healthspan between the control and experimental groups. Also, measurements need to be on the ratio scale, meaning that measures are bounded at 0, so that we can estimate the effect size metric, log response ratio (also known as the ratio of means).

Replication	No specific replication was conducted, although the meta-analysis aimed to replicate results from the zoo analysis in different contexts.
Randomization	This was analysis of existing data so randomization was not conducted.
Blinding	This was analysis of existing data so blinding was not relevant to study.

Behavioural & social sciences study design

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

Study description	
Research sample	
Sampling strategy	
Data collection	
Timing	
Data exclusions	
Non-participation	
Randomization	

Ecological, evolutionary & environmental sciences study design

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

Study description	
Research sample	
Sampling strategy	
Data collection	
Timing and spatial scale	
Data exclusions	
Reproducibility	
Randomization	
Blinding	

Did the study involve field work? ☐ Yes ☐ No

Field work, collection and transport

Field conditions	
Location	
Access & import/export	
Disturbance	

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	NA
Validation	NA

Eukaryotic cell lines

Policy information about cell lines and Sex and Gender in Research

Cell line source(s)	NA
Authentication	NA
Mycoplasma contamination	NA
Commonly misidentified lines (See ICLAC register)	NA

Palaeontology and Archaeology

Specimen provenance	NA
Specimen deposition	NA
Dating methods	NA

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

Ethics oversight	NA

Note that full information on the approval of the study protocol must also be provided 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	Only data from previously published studies is used and this is clearly cited.
Wild animals	Only data from previously published studies is used and this is clearly cited.
Reporting on sex	Sex is always clearly identified.
Field-collected samples	Only data from previously published studies is used and this is clearly cited.
Ethics oversight	NA

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

Clinical data

Policy information about clinical studies

All manuscripts should comply with the ICMJE guidelines for publication of clinical research and a completed CONSORT checklist must be included with all submissions.

Clinical trial registration	NA
Study protocol	NA
Data collection	NA
Outcomes	NA

Dual use research of concern

Policy information about dual use research of concern

Hazards

Could the accidental, deliberate or reckless misuse of agents or technologies generated in the work, or the application of information presented in the manuscript, pose a threat to:

No	Yes	
☒	☐	Public health
☒	☐	National security
☒	☐	Crops and/or livestock
☒	☐	Ecosystems
☒	☐	Any other significant area

Experiments of concern

Does the work involve any of these experiments of concern:

No	Yes	
☐	☐	Demonstrate how to render a vaccine ineffective
☐	☐	Confer resistance to therapeutically useful antibiotics or antiviral agents
☐	☐	Enhance the virulence of a pathogen or render a nonpathogen virulent
☐	☐	Increase transmissibility of a pathogen
☐	☐	Alter the host range of a pathogen
☐	☐	Enable evasion of diagnostic/detection modalities
☐	☐	Enable the weaponization of a biological agent or toxin
☐	☐	Any other potentially harmful combination of experiments and agents

Plants

Seed stocks	NA
Novel plant genotypes	NA
Authentication	NA

ChIP-seq

Data deposition

☐ Confirm that both raw and final processed data have been deposited in a public database such as GEO.

☐ Confirm that you have deposited or provided access to graph files (e.g. BED files) for the called peaks.

Data access links *May remain private before publication.*	NA
Files in database submission	NA
Genome browser session (e.g. UCSC)	NA

Methodology

Replicates	NA
Sequencing depth	NA
Antibodies	NA
Peak calling parameters	NA
Data quality	NA

Software NA

Flow Cytometry

Plots

Confirm that:

☐ The axis labels state the marker and fluorochrome used (e.g. CD4-FITC).

☐ The axis scales are clearly visible. Include numbers along axes only for bottom left plot of group (a 'group' is an analysis of identical markers).

☐ All plots are contour plots with outliers or pseudocolor plots.

☐ A numerical value for number of cells or percentage (with statistics) is provided.

Methodology

Sample preparation NA

Instrument NA

Software NA

Cell population abundance NA

Gating strategy NA

☐ Tick this box to confirm that a figure exemplifying the gating strategy is provided in the Supplementary Information.

Magnetic resonance imaging

Experimental design

Design type NA

Design specifications NA

Behavioral performance measures NA

Imaging type(s) NA

Field strength NA

Sequence & imaging parameters NA

Area of acquisition NA

Diffusion MRI ☐ Used ☐ Not used

Preprocessing

Preprocessing software NA

Normalization NA

Normalization template NA

Noise and artifact removal NA

Volume censoring NA

Statistical modeling & inference

Model type and settings NA

Effect(s) tested NA

Specify type of analysis: ☐ Whole brain ☐ ROI-based ☐ Both

Statistic type for inference (See Eklund et al. 2016)

NA

Correction

NA

Models & analysis

n/a	Involved in the study
☐	☐ Functional and/or effective connectivity
☐	☐ Graph analysis
☐	☐ Multivariate modeling or predictive analysis

Functional and/or effective connectivity

NA

Graph analysis

NA

Multivariate modeling and predictive analysis

NA