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Favorable research environment is a key determinant of research integrity according to a ten-country survey across Central and Eastern Europe

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Our study was designed to investigate research integrity among scientists actively working in biomedicine. Using the unique opportunity of the Alliance for Life Sciences, a networking initiative of leading research institutions and universities in Central and Eastern Europe, we organized our own in-depth survey on research integrity in the countries involved. We employed a standardized questionnaire consisting of 19 closed questions with simple, multiple-choice, or scaled responses to explore the situation regarding research integrity at Alliance for Life Sciences member institutions. The questionnaire was in English language and was administered through the Qualtrics platform anonymously. Finally, 10 institutions from 10 different countries participated in the study and the aggregated group of respondents consisted of 752 scientists. First, the analysis of the obtained data included descriptive frequencies of the responses to all types of questions. Second, the construction and analysis of the model of latent variables was included to verify assumptions about individual aspects of the observed behavior and their interrelationships. Confirmatory factor analysis was applied to verify the domain structure, followed by multivariate analysis of variance to assess the effects of institutional affiliation, gender, seniority, and ethics training. Our data provide the first systematic description of research integrity at the biomedical research institutions in 10 Central and Eastern European countries. Because the majority of our respondents were experienced researchers, our study is really valuable for mapping the state of research integrity in participating countries. The descriptive part of the results brings a detailed insight into the research environment in relation to research integrity, as well as recent and former personal experiences with scientific misconduct. It also covers the personal acceptability of various forms and consequences of scientific misconduct and personal estimations of scientific misconduct. The unique findings of our study came from the model showing the correlations between latent and higher-order variables, which reflect relevant domains of the questionnaire. Moreover, seniority and ethics training were identified as predictors of adherence to the principles of research integrity. These results emphasized the importance of the favorable research environment regarding scientific integrity, which is apparently interconnected with the incidence of various forms of misconduct as experienced recently or in the past. Our study using a model of latent variables yielded unique results that clearly showed the importance of fostering a favorable research environment, especially through systematic education in research integrity and available institutional policies that both reduce the risk of scientific misconduct.

Keywords Research integrity, Biomedical research, Scientific misconduct, Scientific fraud, Fabrication, Falsification, Plagiarism, Questionable research practices, Research environment

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Scientific integrity is widely understood and accepted as an essential cornerstone of research activities, underpinning the trustworthiness and reliability of results and outcomes. In the last few decades of rapid scientific progress and increasing global competition, accompanied by more or less medialized examples of scientific fraud, the phenomenon of scientific misconduct and questionable research practices has begun to be studied systematically[1–3] or with a focus on its special aspects, such as data curation[4–6], statistical analyses[7–9] or authorship issues[10]. As a consequence, research institutions have come under scrutiny for their adherence to standards of research ethics and research integrity[11,12].

Over the past years, several surveys have been published that examine the current state of scientific integrity in a variety of academic and research organizations, with the goal of highlighting both the strengths and challenges of existing institutional frameworks, particularly at the national levels. Such studies have been conducted, for example, in Japan[13], China[14], Norway[15], Hungary[16] and in the Netherlands[17]. In addition, some interesting data from international surveys[18] and meta-analyses are also available[19–21], although the difficulties arising from methodological heterogeneity did not allow a clear and unbiased interpretation of the data analyzed[22].

Furthermore, several studies with a particular focus on Ph.D. students and/or early career researchers have been carried out in the last decade as well. These studies included participants from one research institution, e.g. the School of Medicine of the University of Zagreb, Croatia[23] or the Department of Clinical Research and Department of Regional Health Research, University of Southern Denmark[24], selected or all relevant institutions in one country[25] or selected institutions in one geographic region, namely Scandinavia[26,27]. All of them explored how individuals navigate complex issues such as data management, authorship disputes, conflicts of interest, and the various pressures that can compromise their research integrity. The findings consistently revealed the urgent need for robust oversight mechanisms, transparent reporting procedures, and comprehensive ethics training programs to cultivate an environment of accountability and openness within the scientific community. In the context of research integrity studies, these factors are referred to as key contributors to a healthy, supportive or favorable research environment[23,27–29].

Nevertheless, there are only a few results mapping the situation in the international context. We have therefore seized the unique opportunity offered by the Alliance for Life Sciences, a networking initiative of twelve leading life science institutions and universities from eleven Central and Eastern European countries that aims to bridge the gap in European health research and innovation. With the aim to investigate the situation of research integrity in the member institutions of the Alliance for Life Sciences using a standardized methodology, we adapted the already developed questionnaire to organize our own in-depth survey on research integrity.

Methods

Target group

The purpose of this study was to explore the extent to which academic and research integrity is important to scientists actively engaged in biomedical research. Our survey was conducted under the framework of the international Alliance for Life Sciences (A4L) project covering 12 research institutions in 11 countries of Central and Eastern Europe: Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia (Table 1).

In accordance with this aim, we decided to approach the target group of scientists actively involved in biomedical research at the partner institutions. The term "scientists" was defined as employees involved in biomedical research in the role of researchers. In other words, Ph.D. students without an employment contract were not invited to participate. Similarly, technicians, research nurses and other categories of supporting staff were not addressed. The target group at each institution/institutional unit (Table 1) was defined with the help of the institutional HR departments.

Questionnaire

We used a complex questionnaire designed to identify scientific misconduct and questionable research practices[23], originally based on questionnaires used in similar studies in Scandinavian countries[25,27,28,30]. However, as our target group differs from the previous one for which the questionnaire was originally developed, i.e., medical students, Ph.D. students, and their supervisors[23], we modified the questionnaire by adding the introductory and final blocks of questions. The full version of this improved questionnaire (hereafter referred to as the A4L Questionnaire) is provided (Additional File 2). This A4L Questionnaire was administered in English only.

Our A4L Questionnaire consisted of nineteen questions (Q1-Q19), starting with nine "demographic" questions related to the participant's academic career (Q1-Q7) followed by examining the previous education in "science ethics" (Q8-Q9). We used this generic term "science ethics" instead of "research integrity" because some scientists may not be familiar with the difference between "ethics" and "integrity". In addition, we avoid the field-specific term "bioethics" or "medical ethics" because we also approached scientists from other disciplines who also worked in the biomedical sciences.

Institution name (acronyme) and location Institution / Institutional Unit details	Target group size	Start date	End date
Biomedical Research Center of the Slovak Academy of Sciences (BMC SAS), Bratislava, Slovakia			
BMC SAS *(no internal organizational units)*	315	21.11.2022	20.3.2023
International Clinical Research Center (ICRC), St. Anne's University Hospital, Brno, Czechia			
ICRC *(no internal organizational units)*	No response to invitation.		
Latvian Institute of Organic Synthesis (LIOS), Riga, Latvia			
LIOS *(no internal organizational units)*	195	17.10.2022	13.2.2023
Masaryk University (MUNI), Brno, Czechia			
MUNI Central European Institute of Technology	475	16.12.2022	14.4.2023
MUNI Faculty of Science	407	26.10.2022	22.2.2023
MUNI Faculty of Pharmacy	90	26.10.2022	22.2.2023
MUNI Faculty of Medicine	No response to invitation.		
Medical University of Lodz (MUL), Lodz, Poland			
MUL Faculty of Health Sciences	129	25.11.2022	24.3.2023
MUL Faculty of Medicine and Dentistry	507	26.11.2022	25.3.2023
MUL Faculty of Pharmacy	82	25.11.2022	24.3.2023
Medical University Sofia (MUS), Sofia, Bulgaria			
MUS Faculty of Dental Medicine	345	28.10.2022	24.2.2023
MUS Faculty of Medicine	459	28.10.2022	24.2.2023
MUS Faculty of Pharmacy	200	28.10.2022	24.2.2023
MUS Public Health and Care	211	28.10.2022	24.2.2023
Semmelweis University (SU), Budapest, Hungary			
SU Faculty of Dentistry	381	15.11.2022	14.3.2023
SU Faculty of Medicine	123	21.11.2022	20.3.2023
SU Faculty of Pharmaceutical Sciences	NA	20.12.2022	18.4.2023
University of Ljubljana (UL), Ljubljana, Slovenia			
UL Faculty of Medicine	351	12.12.2022	10.4.2023
University of Medicine and Pharmacy "Carol Davila" (UMFCD), Bucharest, Romania			
UMFCD Faculty of Dentistry	NA	3.11.2022	2.3.2023
UMFCD Faculty of Medicine	No response to invitation.		
UMFCD Faculty of Pharmacy	NA	31.10.2022	27.2.2023
University of Tartu (UT), Tartu, Estonia			
UT	Decision not to participate.		
University of Zagreb (UZ), Zagreb, Croatia			
UZ School of Medicine	517	20.10.2022	16.2.2023
Vilnius University (VU), Vilnius, Lithuania			
VU Center for Life Sciences	282	21.11.2022	20.3.2023
VU Faculty of Medicine	466	21.11.2022	20.3.2023

Table 1. Overview of the institutions and target groups addressed.

Next part of the A4L Questionnaire included multiple-choice questions focusing on personal experiences with scientific misconduct. These five questions mapped participants' experiences with different types of scientific misconduct in the past 12 months (Q10-Q14).

Following part examined participants' personal experiences and attitudes toward the problematic behavior in detail, also through detailed scaled-response questions. The first of them (Q15) addressed the frequency of personal participation in various types of scientific misconduct in the past 3 years. The next question (Q16) measured the personal acceptability of some defined types of scientific misconduct, as well as the willingness to report such scientific misconduct of others and to share the blame and punishment in case of personal involvement. The last question (Q17) of this section measured personal opinions on the frequency of scientific misconduct, the risk of its detection, and the consequences of such detection for the scientists involved.

The penultimate multiple-choice question (Q18) was focused on mapping written policies regarding different types of scientific misconduct. The closing question (Q19) was aimed at the identification of the scientific role of the participant. We adopted the categories of the Contributor Role Taxonomy (CRediT)[31] used for the classification of contributor roles in scientific publications, and it was also administered as a multiple-choice question.

Questionnaire distribution

As a first step, the members of the research team approached the persons responsible (scientific directors, vice-deans for research, etc.) at their home institutions with an invitation to participate in this survey. The invitation was always sent by e-mail in a national language, and the invitation letter was attached in English (Additional File 1). If the person in charge agreed with the participation of his/her home institution or institutional unit (faculty, research center, etc.) in this survey, the link to the online questionnaire was provided for distribution to the scientists of the institution/unit in question. This email was always bilingual, in the national language followed by English. In institutions with more than one institutional unit, each unit sent its own invitation to participate in the survey. Participants with contracts with more than one of these units were asked to respond only once, using the link provided by their main workplace/unit.

Because differences in distribution procedure and willingness to participate in this survey were to be expected not only between A4L project partner institutions, but also between units within an institution, we decided to collect responses from each institutional unit separately, in individual datasets. The co-authors of this article served as institutional coordinators for this survey.

The A4L Questionnaire was administered on the Qualtrics platform and responses were collected in a strictly anonymous setting. Personal data and IP addresses were not collected. As the questionnaire was designed to be completed on a computer, participants were asked not to use smartphones. Participants were also informed of the estimated completion time, which was approximately 10 minutes.

For basic definitions of terms used in the questionnaire, participants were provided with the link to the Glossary on the website of the European Network for Academic Integrity (ENAI) [32] and were encouraged to use it in case of uncertainty.

The survey was conducted between October 2022 and April 2023. For each institutional unit, the link to the questionnaire was always active for 120 days. The detailed overview of the timing is shown in Table 1. The differences in timing reflected the specific circumstances of each participating institution/institutional unit.

Descriptive data analysis

As the questionnaire structure was identical for all the datasets, we evaluated the data as aggregated. This aggregated group of respondents consisted of 752 scientists. The analysis of the obtained data included descriptive frequencies of the responses to all types of questions (simple, multiple-choice, and scaled-response).

Confirmatory factor analysis

We employed confirmatory factor analysis (CFA) to test the hypothesis that the questionnaire domains[23] represent distinct latent variables. This approach allowed us to validate the structure of the domains and estimate their relationships through correlations among the latent factors.

We chose to parcel items in order to improve model parsimony by reducing the complexity of the full model[33]. Details regarding the assignment of individual items to parcels are presented in Table 2.parcels were computed as the sum of their respective items. Parcel factor loadings are presented in Table 3. To justify the use of item parcels, we first ensured that the underlying assumptions were satisfied. Specifically, we examined the internal consistency (Cronbach's α ranging from 0.65 to 0.85, M = 0.74) and confirmed the unidimensionality of the domains via separate CFAs.

Given the high intercorrelations and very similar factual meaning within specific subsets of latent variables, we estimated two higher-order variables: "Threat" (THR, indicated by Common Occurrence" (CO), "High Risk of Detection" (HRD), "Severe Consequences" (SC)) and "Last-Year Misconduct" (LYM, indicated by "Recent FFP Pressure" (RFP), "Recent Misconduct" (RM), "Recent Awareness" (RA), "Recent QRP Pressure" (RQP), and "Recent Consequences" (RC)). No cross-loadings and correlations between residuals were allowed.

The model, analyzed using robust maximum likelihood (RML) with NLMINB optimization, demonstrates satisfactory fit to the data based on several key indices. With 150 parameters and 752 observations (67 missing patterns), the model yielded a chi-square value of 1912.466 (scaled: 1590.742) with 629 degrees of freedom. The Comparative Fit Index (CFI=0.923, robust CFI=0.932) and Tucker-Lewis Index (TLI=0.914, robust TLI=0.924) approach the recommended threshold of 0.95, indicating good fit. The Root Mean Square Error of Approximation (RMSEA=0.052, robust RMSEA=0.049) with its 90 % confidence interval (0.049-0.055; robust: 0.046-0.053) and the Standardized Root Mean Square Residual (SRMR=0.057) both fall below their respective cutoff values of 0.06 and 0.08, further supporting the model's adequacy. All data related to the construction and analysis of this model are provided (Additional File 3). For subsequent analyses, we estimated the values of all the latent variables as regression scores.

General linear model (MANOVA)

Latent variable scores were analyzed using a General Linear Model (multivariate ANOVA) in SPSS 31.0 to examine the hypothesized effects of respondent characteristics (institutional background, gender, seniority, doctoral supervision, and ethics training) on the questionnaire's core domains. We chose this strategy to reduce the complexity of the data into a manageable and interpretable exploratory framework.

We assessed the assumption of homogeneity of variance using Levene's test. When all predictors were included, the assumption was violated for half of the dependent variables: Unacceptable Misconduct ($F=1.57$, $p<0.001$), Former Misconduct ($F=1.58$, $p<0.001$), Reporting Obligation ($F=1.44$, $p<0.001$), and Last Year Misconduct ($F=1.51$, $p<0.001$).

However, it is evident that this violation is driven by a single predictor – institutional affiliation – which reflects the unavoidable imbalance in the sample structure. When this predictor is excluded, the assumption of homogeneity of variance is met for all dependent variables. Given the substantial sample size ($N=752$) and the

Acronym and description of the latent variable	No. of the answer included	Parcel assignment	Description of situation or behavior covered by this latent variable
Recent FFP Pressure (RFP) Respondent experienced pressure to do FFP recently, i.e. within the last 12 months.	A10_1	RFP_1	Object of pressure: Fabricate data
	A10_2	RFP_2	Object of pressure: Falsify data
	A10_3	RFP_1	Object of pressure: Plagiarize data
	A10_4	RFP_2	Object of pressure: Plagiarize publications (in whole or in part)
Recent Misconduct (RM) Respondent performed misconduct (FFP or QRP) recently, i.e. within the last 12 months.	A11_1	RM_1	Have you: Fabricated data
	A11_2	RM_2	Have you: Falsified data
	A11_3	RM_2	Have you: Plagiarized data
	A11_4	RM_1	Have you: Plagiarized publications (in whole or in part)
	A11_5	RM_3	Have you: Presented results in some other misleading way
Recent Awareness (RA) Respondent is aware of FFP or QRP done by anyone else recently, i.e. within the last 12 months.	A12_1	RA_1	Anyone: Fabricated data
	A12_2	RA_2	Anyone: Falsified data
	A12_3	RA_1	Anyone: Plagiarized (in any way)
	A12_4	RA_2	Anyone: Presented results in some other misleading way
Recent QRP Pressure (RQP) Respondent experienced pressure to perform QRP recently, i.e. within the last 12 months.	A10_5	RQP_3	Object of pressure: Present results in some other misleading way
	A13_1	RQP_1	Exposed: Inclusion or ordering of authors
	A13_2	RQP_2	Exposed: Design/method
	A13_3	RQP_3	Exposed: Analysis
	A13_4	RQP_1	Exposed: Results
Recent Consequences (RC) Respondent experienced consequences of scientific misconduct recently, i.e., within the last 12 months.	A14_1	RC_1	Affected: Ethical
	A14_2	RC_2	Affected: Legal
	A14_3	RC_1	Affected: Methodological
	A14_4	RC_2	Affected: Any other aspect
Former Misconduct (FM) Respondent reported any experience (active or passive) with scientific misconduct (FFP or QRP) within the last three years.	A15_1	FM_1	Fabricated data?
	A15_2	FM_2	To confirm a hypothesis, selectively deleted or changing data after performing data analysis?
	A15_3	FM_3	Deleted data before performing data analysis?
	A15_4	FM_1	Concealed results that contradicted previous research you published?
	A15_5	FM_2	Used phrases or ideas of others without their permission?
	A15_6	FM_3	Used/ing phrases or ideas of others without citation?
	A15_7	FM_1	Turned a blind eye to colleagues' use of flawed data or questionable interpretation of data?
	A15_8	FM_2	Modified the results or conclusions of a study under pressure from an organization that (co-) funded the research?
	A15_9	FM_3	Not published (part of) the results of a study?
	A15_10	FM_1	Deliberately not mentioned an organization that funded your research in the publication of your study?
	A15_11	FM_2	Added one or more authors to a report who did not qualify for authorship (honorary author)?
	A15_12	FM_3	Selectively modified data after performing data analysis to confirm a hypothesis?
	A15_13	FM_1	Reported/ing a downwardly rounded p value (e.g. reporting that a p value of .054 is less than .05)?
	A15_14	FM_2	Reported an unexpected finding as having been hypothesized from the start?
	A15_15	FM_3	Decided whether to exclude data after looking at the impact of doing so on the results?
	A15_16	FM_1	Decided to collect more data after seeing that the results were almost statistically significant?
	A15_17	FM_2	Omitted a contributor who deserved authorship from the author's list?
	A15_18	FM_3	Stopped collecting data earlier than planned because the result at hand already reached statistical significance without formal stopping rules?
	A15_19	FM_1	Deliberately failed to mention important aspects of the study in the paper?
	A15_20	FM_2	Not disclosed a relevant financial or intellectual conflict of interest?
	A15_21	FM_3	Spread results over more papers than needed to publish more papers ('salami slicing')?
	A15_22	FM_1	Used confidential reviewer information for own research or publications?
Unacceptable Misconduct (UM) Respondent identified some FFP or QRP practices as never appropriate.	A16_1	UM_1	It is never appropriate to report experimental data that have been created without actually having conducted the experiment.
	A16_2	UM_2	It is never appropriate to alter experimental data to make an experiment look better than it actually was.
	A16_3	UM_3	It is never appropriate to try a variety of different methods of analysis until one is found that yields a result that is statistically significant.
	A16_4	UM_1	It is never appropriate to take credit for the words or writing of someone else.
	A16_5	UM_2	It is never appropriate to take credit for the data generated by someone else.
	A16_6	UM_3	It is never appropriate to take credit for the ideas generated by someone else.
Continued			

Acronym and description of the latent variable	No. of the answer included	Parcel assignment	Description of situation or behavior covered by this latent variable
Self-Justified Misconduct (SJM) Respondent indicated some FFP or QRP practices as acceptable under certain conditions.	A16_7	SJM_1	If you are confident of your findings, it is acceptable to selectively omit contradictory results to expedite publication.
	A16_8	SJM_2	If you are confident of your findings, it is acceptable to falsify or fabricate data to expedite publication.
	A16_9	SJM_3	It is more important that data reporting be completely truthful in a publication than in a grant application.
Reporting Obligation (RO) Respondent accepted the obligation to act in case of witnessed misconduct.	A16_10	RO_1	If you witness someone committing research misconduct, you have an ethical obligation to act.
	A16_11	RO_2	If you had witnessed a co-worker or peer committing research misconduct, you would be willing to report that misconduct to a responsible official.
	A16_12	RO_3	If you had witnessed a supervisor or principal investigator committing research misconduct, you would be willing to report that misconduct to a responsible official.
Shared Responsibility (SR) Respondent accepted shared responsibility for a published paper.	A16_13	SR_1	If fabricated data are discovered in a published paper, all co-authors must equally share in the blame.
	A16_14	SR_2	If fabricated data are discovered in a published paper, all co-authors must get the same punishment.
Common Occurrence (CO) Respondent estimated various forms of misconduct to be common in his/her area of research.	A17_1	CO_1	Severe scientific misconduct (fabrication, falsification, plagiarism) is common in my area of research.
	A17_2	CO_2	Less severe scientific misconduct (less than fabrication, falsification, plagiarism) is common in my area of research.
	A17_3	CO_3	Authorship misconduct (inappropriate authorship) is common in my area of research.
High Risk of Detection (HRD) Respondent indicated a high risk of being detected in case of various forms of misconduct.	A17_4	HRD_1	The risk of being detected if you commit severe scientific misconduct in my area of research is high.
	A17_5	HRD_2	The risk of being detected if you commit less severe scientific misconduct in my area of research is high.
	A17_6	HRD_3	The risk of being detected if you commit authorship misconduct in my area of research is high.
Severe Consequences (SC) Respondent expected severe consequences of being detected in committing various forms of misconduct.	A17_7	SC_1	The consequences of being detected if you commit severe scientific misconduct in my area of research are severe (loss of scientific career, loss of funding, retraction of publications)
	A17_8	SC_2	The consequences of being detected if you commit less severe scientific misconduct in my area of research are severe
	A17_9	SC_3	The consequences of being detected if you commit authorship misconduct in my area of research are severe
Written Policy (WP) Respondent reported the written policies covering various types of scientific misconduct in his/her department.	Q21_1	WP_1	Policy: Application for funds
	Q21_2	WP_2	Policy: Use of funds
	Q21_3	WP_3	Policy: Changes in design/method
	Q21_4	WP_1	Policy: Changes in results
	Q21_5	WP_2	Policy: Fabrication of data
	Q21_6	WP_3	Policy: Falsification of data
	Q21_7	WP_1	Policy: Handling of scientific authorship
	Q21_8	WP_2	Policy: Plagiarism
	Q21_9	WP_3	Policy: Duplicate publication (publishing the same twice)
	Q21_10	WP_1	Policy: Harassment

Table 2. List of items in the model of latent variables. The "Parcel assignment" column indicates the specific parcel to which a variable was allocated.

robustness of the MANOVA, we argue that retaining 'Institution' in the model is justified, as it provides a more accurate representation of the collected data.

Furthermore, visual inspection of Q-Q plots confirmed that the distribution of residuals is approximately normal.

Ethical considerations

The intent to conduct this survey was presented to the institutional research ethics committees (RECs). Each REC was provided with the full version of the A4L questionnaire along with a cover letter. Nevertheless, this type of research is subject to different types of ethical evaluation according to specific national legislation. For this reason, our survey was either subjected to ethical review and approved to be conducted (Croatia, Hungary, Slovenia) or a statement was issued that ethical review was not required (Bulgaria, Czechia, Latvia, Lithuania, Poland, Romania, Slovakia).

The survey itself was administered online only and was completely anonymous. Under these conditions, no written consent was obtained from the respondents. Nevertheless, respondents were informed about the format, length and anonymity measures of the questionnaire on the introductory screen of the survey. By clicking the 'Start the survey' button, respondents provided their implicit informed consent to participate. Such a procedure is fully compliant with ethical standards for anonymous online surveys and fully meets the requirements of confidentiality and voluntary participation.

Acronym and description of the latent variable	Parcel	Factor loading
Recent FFP Pressure (RFP) Respondent experienced pressure to do FFP recently, i.e. within the last 12 months.	RFP_1	0.738
	RFP_2	0.825
Recent Misconduct (RM) Respondent performed misconduct (FFP or QRP) recently, i.e. within the last 12 months.	RM_1	0.725
	RM_2	0.805
	RM_3	0.421
Recent Awareness (RA) Respondent is aware of FFP or QRP done by anyone else recently, i.e. within the last 12 months.	RA_1	0.805
	RA_2	0.946
Recent QRP Pressure (RQP) Respondent experienced pressure to perform QRP recently, i.e. within the last 12 months.	RQP_1	0.603
	RQP_2	0.649
	RQP_3	0.824
Recent Consequences (RC) Respondent experienced consequences of scientific misconduct recently, i.e., within the last 12 months.	RC_1	0.830
	RC_2	0.792
Former Misconduct (FM) Respondent reported any experience (active or passive) with scientific misconduct (FFP or QRP) within the last three years.	FM_1	0.846
	FM_2	0.787
	FM_3	0.793
Unacceptable Misconduct (UM) Respondent identified some FFP or QRP practices as never appropriate.	UM_1	0.894
	UM_2	0.948
	UM_3	0.806
Self-Justified Misconduct (SJM) Respondent indicated some FFP or QRP practices as acceptable under certain conditions.	SJM_1	0.866
	SJM_2	0.823
	SJM_3	0.370
Reporting Obligation (RO) Respondent accepted the obligation to act in case of witnessed misconduct.	RO_1	0.706
	RO_2	0.937
	RO_3	0.891
Shared Responsibility (SR) Respondent accepted shared responsibility for a published paper.	SR_1	0.971
	SR_2	0.907
Common Occurrence (CO) Respondent estimated various forms of misconduct to be common in his/her area of research.	CO_1	0.792
	CO_2	0.908
	CO_3	0.659
High Risk of Detection (HRD) Respondent indicated a high risk of being detected in case of various forms of misconduct.	HRD_1	0.851
	HRD_2	0.957
	HRD_3	0.708
Severe Consequences (SC) Respondent expected severe consequences of being detected in committing various forms of misconduct.	SC_1	0.838
	SC_2	0.970
	SC_3	0.839
Written Policy (WP) Respondent reported the written policies covering various types of scientific misconduct in his/her department.	WP_1	0.933
	WP_2	0.930
	WP_3	0.942

Table 3. Latent variables and parcel factor loadings. The “Factor loading” column displays the standardized regression coefficient by which the respective parcel loads onto the given factor.

Results

Participation in the study

As shown in Table 1, 10 institutions from 10 different countries finally participated in this study and 21 individual data sets were collected in total.

The evaluation of response rate consists of two parameters – reaction rate and completion rate (Table 4). The reaction rate was defined as the number of participants who opened the online A4L Questionnaire using the link provided in the invitation e-mail. This parameter varied from 71.54 % (Semmelweis University, Faculty of Medicine) to 5.33 % (Medical University of Lodz, Faculty of Medicine and Dentistry). Completion rate was defined as the number of respondents who fulfilled the entire questionnaire and it varied from 34.15 % (Semmelweis University, Faculty of Medicine) to 2.32 % (Medical University Sofia, Faculty of Dental Medicine), although in three other cases the completion rate was also similarly very low: 2.36 % (Semmelweis University, Faculty of Dentistry), 2.56 % (Medical University of Lodz, Faculty of Medicine and Dentistry), and 3.50 (Medical University Sofia, Faculty of Pharmacy). Interestingly, the response rate, i.e., the ratio of the completion rate to the reaction rate, which indicates the willingness of those who have already opened the survey to complete it, varied

Institution / Institutional Unit	Target group	Reaction rate		Completion rate		Response Rate
BMC SAS	315	128	40.63 %	76	24.13 %	0.59
LIOS	195	106	54.36 %	49	25.13 %	0.46
MUNI Central European Institute of Technology	475	79	16.63 %	38	8.00 %	0.48
MUNI Faculty of Science	407	153	37.59 %	81	19.90 %	0.53
MUNI Faculty of Pharmacy	90	34	37.78 %	15	16.67 %	0.44
MUL Faculty of Health Sciences	129	43	33.33 %	17	13.18 %	0.40
MUL Faculty of Medicine and Dentistry	507	27	5.33 %	13	2.56 %	0.48
MUL Faculty of Pharmacy	82	12	14.63 %	5	6.10 %	0.42
MUS Faculty of Dental Medicine	345	28	8.12 %	8	2.32 %	0.29
MUS Faculty of Medicine	459	62	13.51 %	33	7.19 %	0.53
MUS Faculty of Pharmacy	200	15	7.50 %	7	3.50 %	0.47
MUS Public Health and Care	211	23	10.90 %	14	6.64 %	0.61
SU Faculty of Dentistry	381	24	6.30 %	9	2.36 %	0.38
SU Faculty of Medicine	123	88	71.54 %	42	34.15 %	0.48
SU Faculty of Pharmaceutical Sciences	NA	6	NA	3	NA	0.50
UL Faculty of Medicine	351	117	33.33 %	79	22.51 %	0.68
UMFCD Faculty of Dentistry	NA	39	NA	27	NA	0.69
UMFCD Faculty of Pharmacy	NA	65	NA	35	NA	0.54
UZ School of Medicine	517	123	23.79 %	81	15.67 %	0.66
VU Center for Life Sciences	282	104	36.88 %	53	18.79 %	0.51
VU Faculty of Medicine	466	121	25.97 %	67	14.38 %	0.55

Table 4. Response rate achieved. Response rate was calculated as the ratio of the completion rate to the reaction rate. Reaction rate is the number of participants who opened the online A4L Questionnaire using the link provided in the invitation e-mail. Completion rate is the number of respondents who fulfilled the entire questionnaire. Only institutions and institutional units willing to participate in the survey are included. BMC SAS, Biomedical Research Center of the Slovak Academy of Sciences. LIOS, Latvian Institute of Organic Synthesis. MUNI, Masaryk University. MUL, Medical University of Lodz. MUS, Medical University Sofia. SU, Semmelweis University. UL, University of Ljubljana. UMFCD, University of Medicine and Pharmacy "Carol Davila". UZ, University of Zagreb. VU, Vilnius University.

between 0.40 and 0.60 in most of the participating institutions or institutional units, regardless of the percentage of respondents participating (Table 4).

Demographic and professional characteristics of the respondents

This overview describing the respondents' backgrounds in detail is provided in Fig. 1. The obtained data on gender (Fig. 1a) showed that 56.6 % of respondents identified as female, 42.2 % identified as male, and 0.9 % chose not to disclose their gender (Q5). Regarding professional background (Fig. 1b), 53.3 % of respondents had a healthcare background, 44.9 % did not, and 1.9 % chose not to answer this question (Q6). The specialization of their doctoral studies (Fig. 1c) was in basic research in the life sciences for 63.2 % of respondents, in clinical research for 29.0 %, and in other disciplines for 11.8 % (Q7). Regarding professional history (Fig. 1d), 91 % of respondents completed their undergraduate studies in the same country where they were working at the time of the survey (Q1) and there was only a very small change for doctoral studies, with 89 % of respondents reporting that they also completed their doctoral studies in the same country (Q2).

In terms of career length (Fig. 1e), 23.7 % of respondents had worked as researchers for up to 5 years, 16.2 % had worked as researchers for 6-10 years, 14.8 % had worked as researchers for 11-15 years, and 44.5 % had worked as researchers for more than 15 years (Q3). For more detailed understanding of the scientific role and experience of participants, the multiple-choice question adopting the categories of CRediT[34] was included (Q15),the responses to this question are summarized in Table 5. In addition to the respective category in CRediT, the supervision experience was mapped in more detail (Fig. 1f) : 51.3 % of respondents reported none, and 31.9 % of respondents had supervised up to 5 students. 10.1 % of respondents had supervised 6-10 students, 3.3 % had supervised 11-15 students, and 2.4 % had supervised more than 15 students during their career. 0.9 % of respondents did not report the number of students they supervised (Q4).

Research environment

The research environment in the context of research integrity (Fig. 2) was evaluated in terms of previous education of the respondents – although this could be obtained anywhere –, and the existence of written institutional policies on specified sensitive issues.

The situation regarding previous education (Fig. 2a) in science ethics was mapped for both undergraduate (Q8) and doctoral (Q9) studies; the term "education" encompassed both individual lectures and specialized

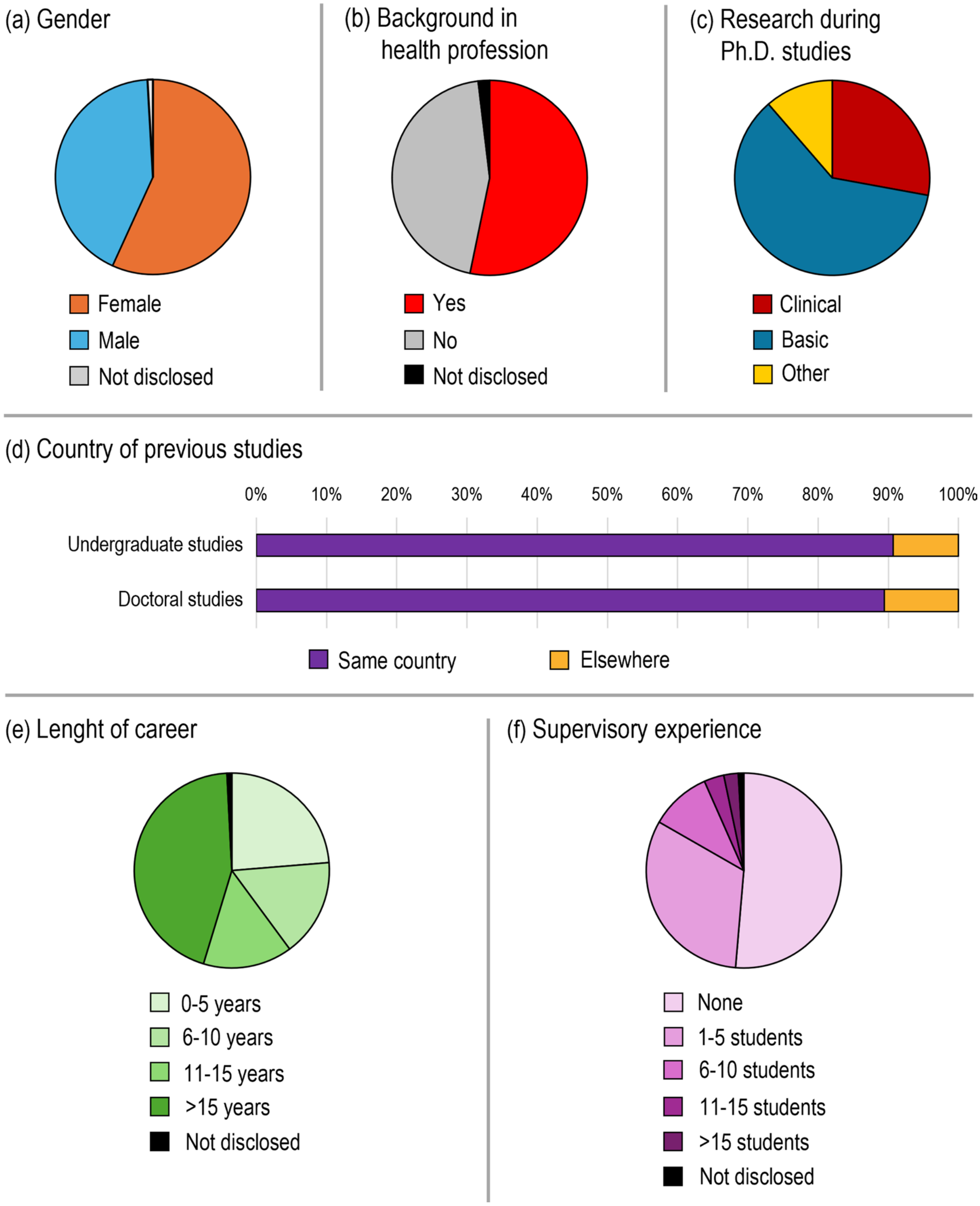

Fig. 1. Demographic and professional characteristics of the respondents.

courses. 36.3 % of respondents reported this type of education during their undergraduate studies and 32.8 % of respondents during their doctoral studies. Interestingly, 8.5 % of respondents did not remember whether or not they had completed any kind of science ethics education for their undergraduate studies, and 9.2 % did not remember this for their doctoral studies. No education in science ethics confirmed 55.2 % for undergraduate studies, and 58.1 % for doctoral studies.

The existence of written institutional policies (Fig. 2b) varied according to the specific issue covered by the respective policy. Not surprisingly, the most common topic of written policy was plagiarism, with 45.3 % of respondents reporting this policy at their home institutions, followed by rules for the use of funds (42.2 %). In contrast, the least frequent written policies were reported for changes in design/methods (16.5 %) and changes in results (18.4 %). However, it is also noteworthy that the proportion of respondents who were unsure whether such a policy existed at their home institution was relatively high and stable, ranging from 32.0 % to 47.8 %.

Recent personal experiences with scientific misconduct

The next set of multi-choice questions was intended to identify personal experiences with defined categories of scientific misconduct in the past 12 months. The results are summarized in Fig. 3.

Role according to CRediT (listed in alphabetical order)	Percentage of respondents who identified themselves with the role
Conceptualization	75.7 %
Data curation	28.2 %
Formal analysis	53.9 %
Funding acquisition	42.7 %
Investigation	79.4 %
Methodology	75.0 %
Project administration	40.0 %
Resources	47.3 %
Software	12.8 %
Supervision	53.1 %
Validation	42.0 %
Visualization	64.6 %
Writing – Original Draft	82.8 %
Writing – Review & Editing	73.5 %

Table 5. Scientific role(s) of the respondents. The categories of the Contributor Role Taxonomy (CRediT) were used in this question (Q19) and the question was administered as multiple-choice.

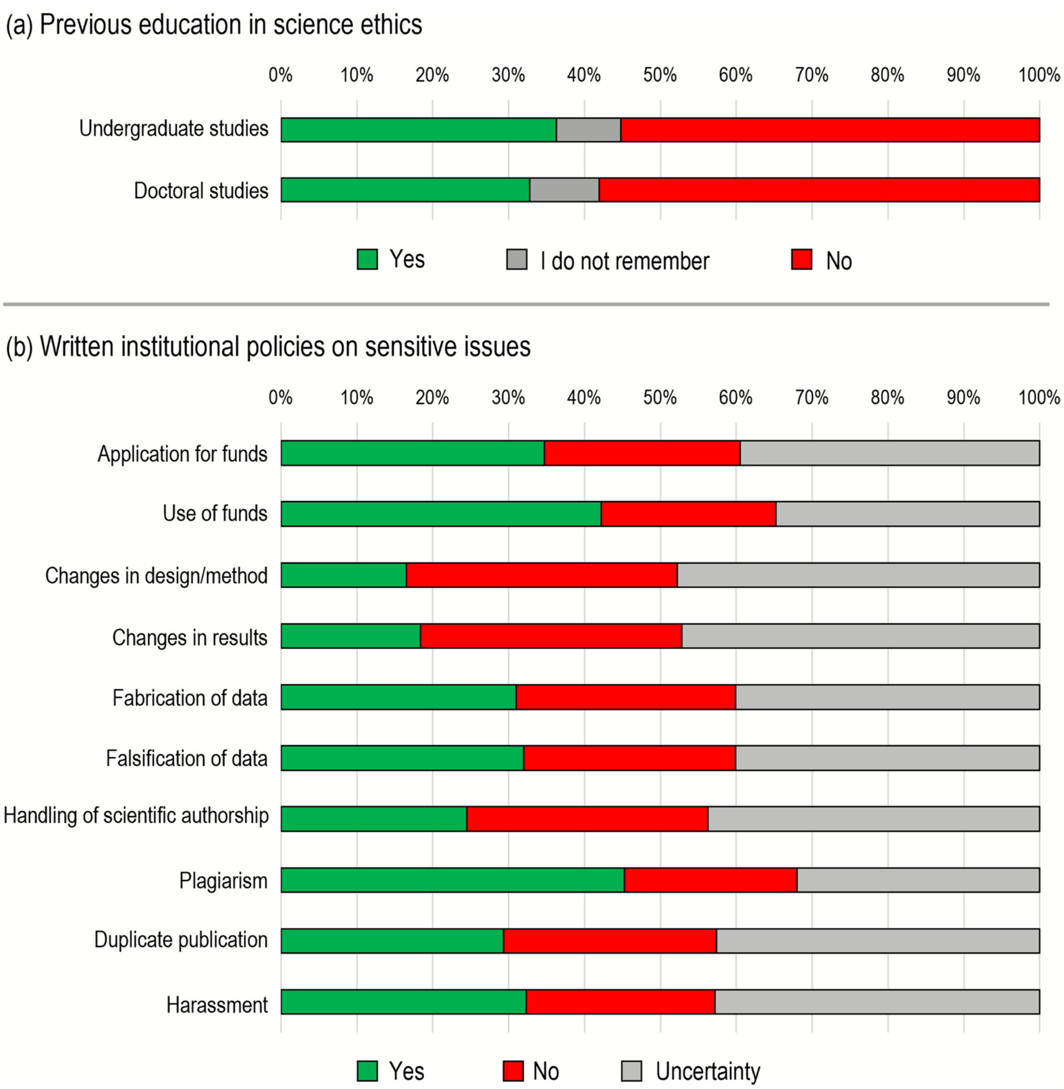

Fig. 2. Research environment in the area of research ethics and research integrity.

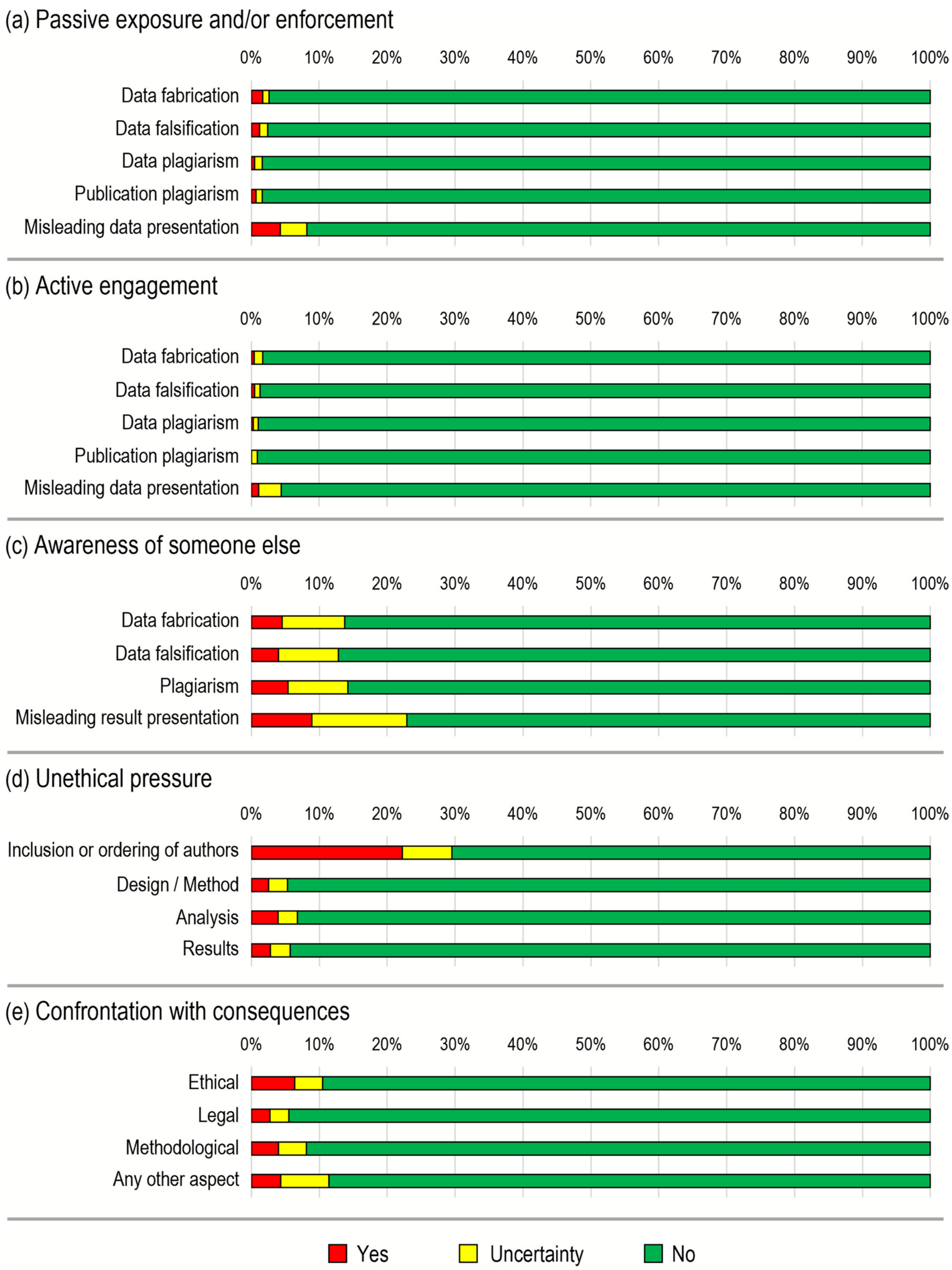

Fig. 3. Personal experiences with scientific misconduct in the past 12 months.

First, respondents were asked about their personal confrontation with scientific misconduct of varying degrees of severity – fabrication, falsification or plagiarism of data, misleading presentation of data, and plagiarism of publications. In order to distinguish the level of personal encounter, the questions were directed at passive exposure / enforcement without action (Fig. 3a) or active engagement (Fig. 3b). The next question was focused on awareness of scientific misconduct in the respondent's own department; however, for this question, the data plagiarism and misleading presentation of data were combined into a category of misleading presentation of results (Fig. 3c). Not surprisingly, the levels of confession rate for both passive exposure / enforcement and active engagement were extremely low. For passive exposure / enforcement (Fig. 3a), confirmed experience ranged from 0.5 to 4.3 % and uncertainty about the situation from 0.9 to 3.9 %. Active engagement in scientific misconduct (Fig. 3b) was confirmed by up to 1.1 % of respondents, with an additional up to 3.3 % reporting uncertainty about the situation. In contrast, the awareness of scientific misconduct by colleagues (Fig. 3c) increased up to 8.9

%, with an additional 14 % of respondents unsure about the situation. For all three questions, experience with scientific misconduct was most frequently reported in the category of misleading presentation of data / results.

Following two questions also mapped the respondent's experience within the period of the past 12 months with the use of different categorizations of scientific misconduct. First of them was aimed at personal exposure to "unethical pressure" again, but with the use of broader categories covering the subject of such a pressure (Q13). As these categories did not match the ones used in Q10, the frequency of reported experience was almost double ranging from 2.5 % regarding design or methods to 22.2 % regarding authorship issues accompanied by uncertainty between 2.8 and 7.1 % for the respective categories (Fig. 3d). The last question in this part of the survey focused on the personal experience with the consequences of scientific misconduct (Q14). The reported experience ranged from 2.7 % of respondents affected by legal consequences to 6.4 % of those affected by ethical consequences (Fig. 3e).

Three-year personal experiences with scientific misconduct

The next scaled-response question was aimed at the frequency of personal participation in specified types of scientific misconduct in the past 3 years (Q15). The options included both the severe forms of scientific misconduct, i.e. fabrication, falsification and plagiarism (FFP), as well as other questionable research practices (QRP), which are considered mild to moderate forms of scientific misconduct. The results are summarized in Fig. 4.

The results showed that the most frequently reported form of scientific misconduct was gifted authorship (45.4 % of experienced respondents in total), followed by N-hacking (34.7 % of experienced respondents in total) and retention of results (28.0 % of experienced respondents in total). On the other hand, the least common misconduct was hidden funding in publication and for undisclosed conflict of interests (1.5 % of experienced

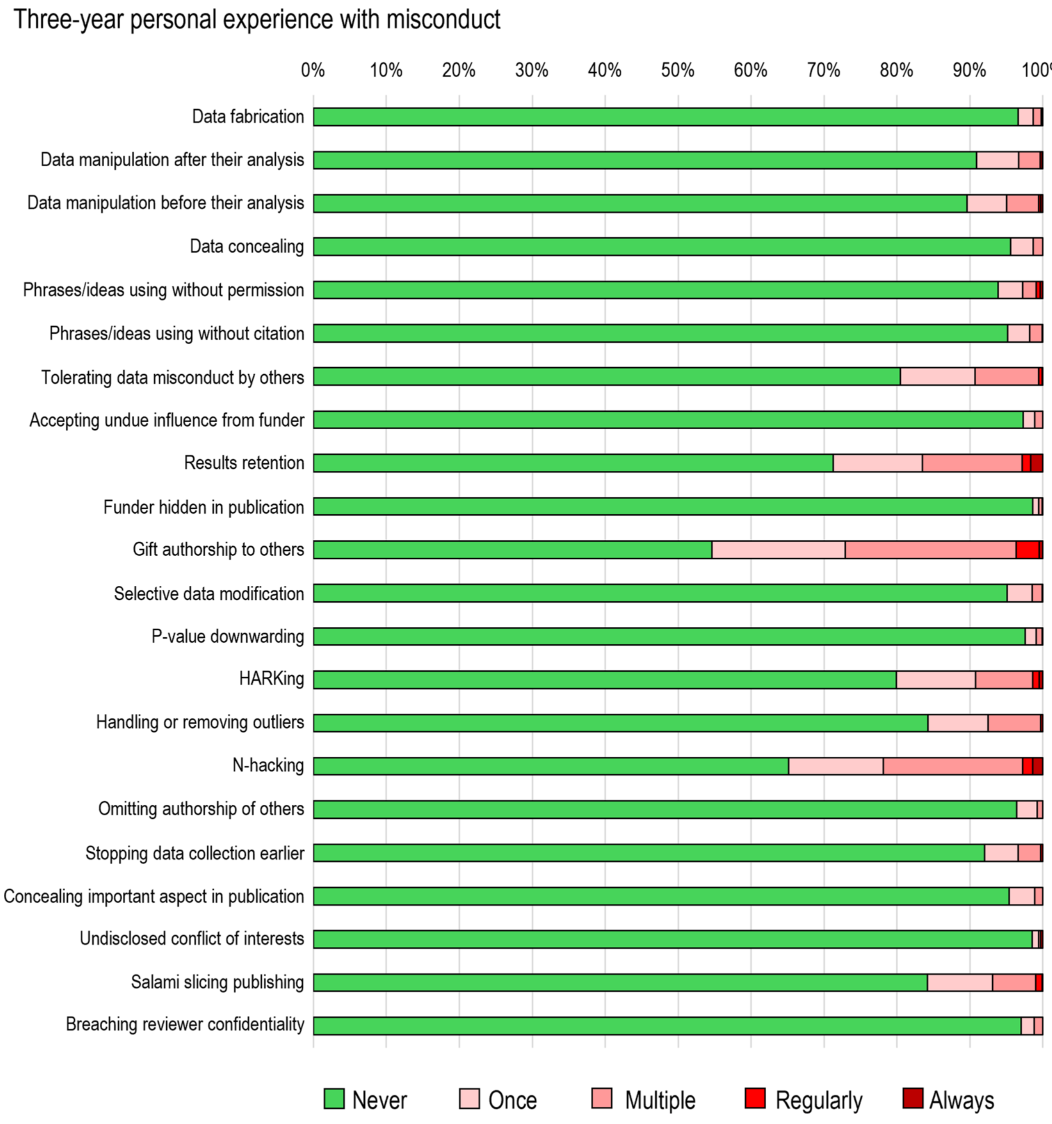

Fig. 4. Three-year personal experiences with different forms of scientific misconduct.

respondents in total in both cases), followed by accepting undue influence from funder (2.7 % of experienced respondents in total) and breach of reviewer confidentiality (3.0 % of experienced respondents in total).

Personal acceptability of various forms and consequences of scientific misconduct

The next scaled-response question was focused on the personal acceptability of some defined forms of scientific misconduct, both FFP and QRP, as well as the willingness to act as a whistleblower in case of others or to share the blame and punishment in case of personal involvement (Q16). The results are summarized in Fig. 5.

The results on personal acceptability of specified forms of scientific misconduct (Fig. 5a) showed that manipulating data in a project proposal was the most acceptable practice (42.9 % of respondents), followed by removing outliers in the case of confidence in findings (26.4 % of respondents). In contrast, the least acceptability was reported for data falsification (5.2 % of respondents), tightly followed by stealing of ideas (5.3 % of respondents), plagiarism (5.4 % of respondents) and stealing of data (5.8 % of respondents).

The willingness to act in the case of someone's misconduct (Fig. 5b) was reported as more or less acceptable by 75.0 % of respondents; however, the willingness to act as a whistleblower decreased to 61.6 % in the case of a colleague and to 59.2 % in the case of a supervisor or principal investigator. In terms of consequences in case of severe misconduct, e.g. data fabrication (Fig. 5b), the sharing of the blame was more or less acceptable for 47.4 % of respondents. However, the sharing of punishment in the same situation was more or less acceptable for 38.3 % of respondents.

Personal estimation of misconduct

This scaled-response question was focused on the personal estimation of misconduct in one's own field of research in terms of common occurrence, risk of detection, and severe consequences of detection (Q17). For each of these aspects, three forms of misconduct were assessed: severe or mild scientific misconduct (without further specification) and authorship misconduct. The results are summarized in Fig. 6.

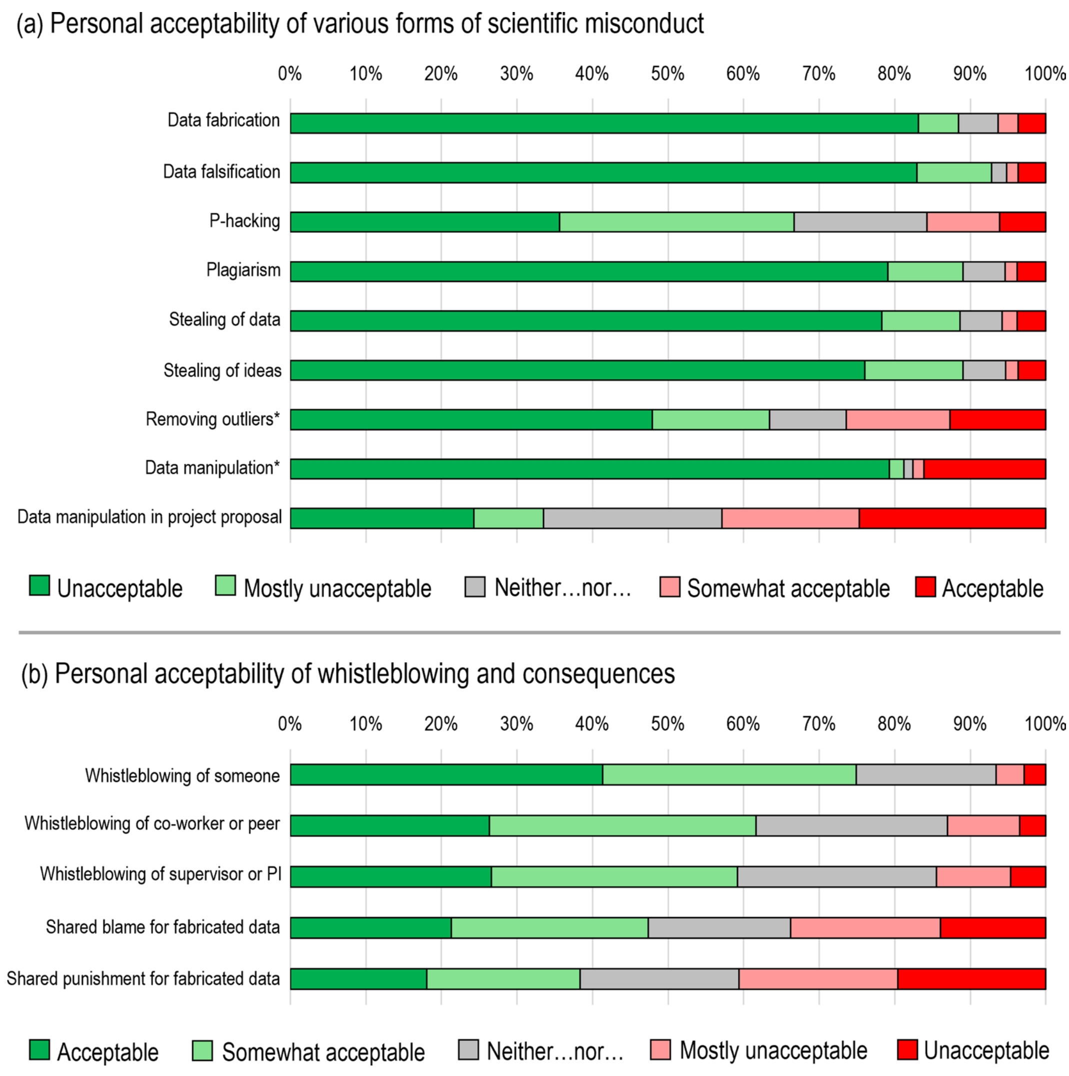

Fig. 5. Personal acceptability of various forms and consequences of scientific misconduct.

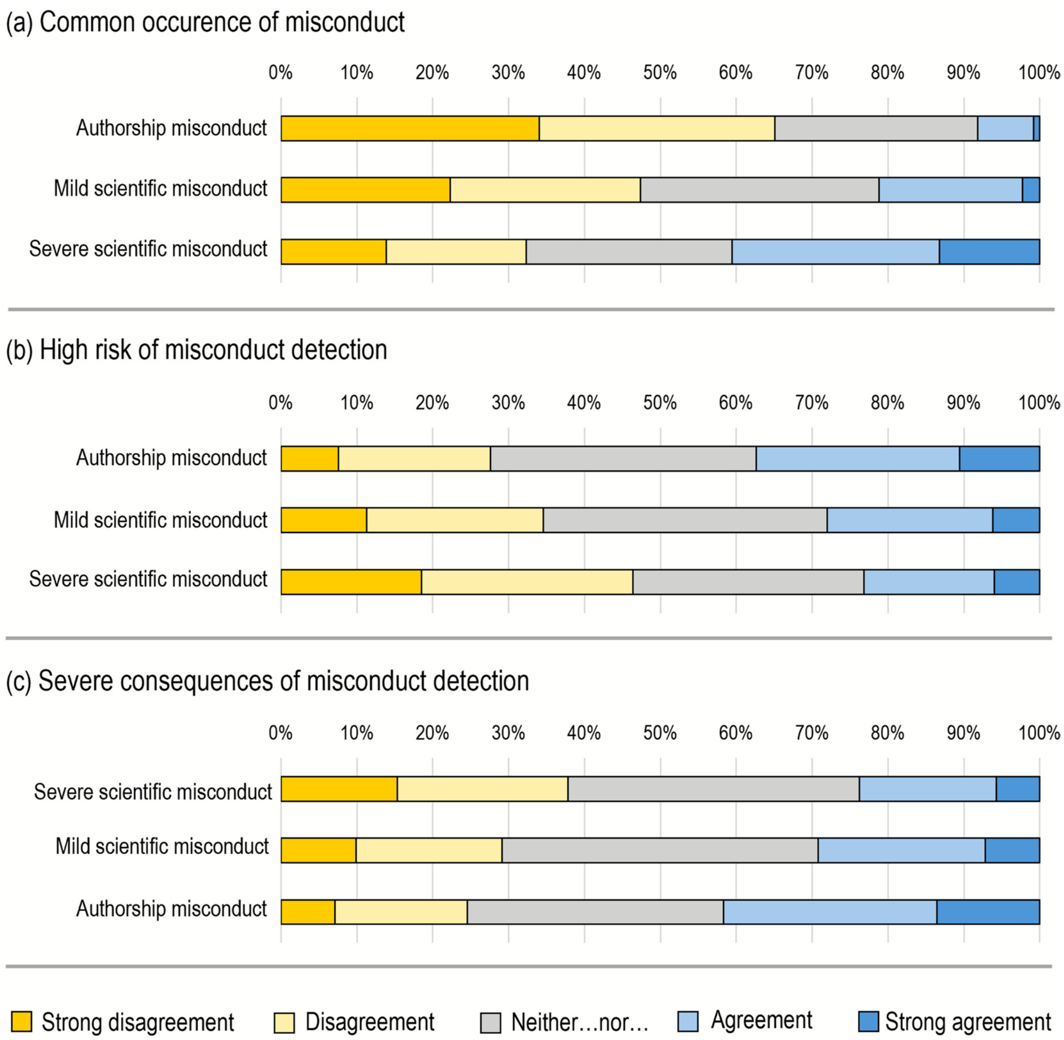

Fig. 6. Personal estimation of misconduct in one's own field of research.

Respondents estimated authorship misconduct to be the most frequent, followed by mild and severe misconduct (Fig. 6a). Nevertheless, the estimation of the high risk of being detected showed an inverse pattern: the respondents expected the highest probability of detection for severe scientific misconduct, followed by mild and authorship misconduct (Fig. 6b). Finally, the consequences of being detected were also estimated to be severe also for severe scientific misconduct, followed by mild misconduct and authorship misconduct (Fig. 6c).

Confirmatory factor analysis

All significant relationships ($p < 0.05$) among latent variables are summarized as a correlation matrix (Table 6) and plot visualization (Fig. 7). The complete data for this analysis are available as Additional File 3.

These results clearly showed that the latent variable called "Former Misconduct" (FM), which is defined as any experience with scientific misconduct (both passive and active) during the past three years, has a strong positive correlation ($r = 0.575$) with "Last Year Misconduct" (LYM), which is a higher-order variable that encompasses any recent experience with any form of scientific misconduct during the last 12 months. In detail, LYM encompasses the latent variables "Recent FFP Pressure" (RFP), "Recent Misconduct" (RM), "Recent Awareness" (RA), "Recent QRP Pressure" (RQP), and "Recent Consequences" (RC).

The moderate negative correlation ($r = -0.400$) was found between the higher-order variable LYM and another higher-order variable called "Threat" (THR), which encompasses the latent variables "Common Occurrence" (CO), "High Risk of Detection" (HRD), and "Severe Consequences" (SC). In other words, THR reflects scientific misconduct as a real threat to the field of biomedicine in terms of its high incidence rate, high risk of detection, and serious consequences for those who commit it. Similarly, we found the lower negative correlation ($r = -0.281$) between THR and FM.

The latent variable "Unacceptable Misconduct" (UM), i.e., the unacceptability of both FFP and QRP, positively correlates with latent variables "Reporting Obligation" (RO) ($r = 0.291$) and "Shared Responsibility" (SR) ($r = 0.154$). Conversely, latent variable FM negatively correlates with the latent variables RO ($r = -0.296$) and SR ($r = -0.170$).

Variable	FM	RO	SR	UM	WP	*LYM	*THR
FM	1	-0.296	-0.170	-0.148	-0.156	0.575	-0.281
RO	-0.296	1	0.298	0.291	0.128	-0.243	0.271
SR	-0.170	0.298	1	0.154	0.021	-0.104	0.196
UM	-0.148	0.291	0.154	1	0.034	-0.034	0.106
WP	-0.156	0.128	0.021	0.034	1	-0.160	0.296
*LYM	0.575	-0.243	-0.104	-0.034	-0.160	1	-0.400
*THR	-0.281	0.271	0.196	0.106	0.296	-0.400	1

Table 6. Correlation matrix with significant relationships among latent variables and higher-order variables. Higher-order variables are indicated by asterisks. Significant positive correlations are indicated by light green background, significant negative correlations by light red background.

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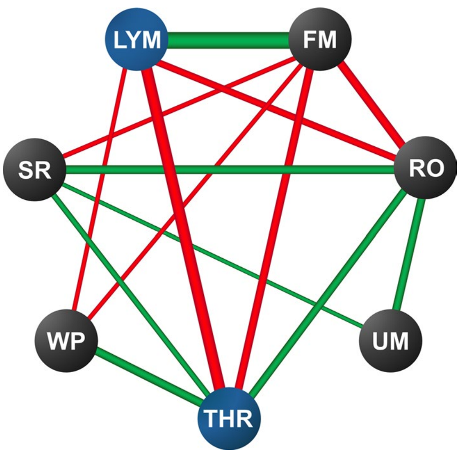

Fig. 7. Confirmatory factor analysis plot summarizing the significant correlations. Latent variables (black) and higher-order variables (dark blue) are shown as spheres. Significant positive correlations (r>0.150, green) and negative correlations (r<-0.150, red) are shown as connecting lines. Line thickness is proportional to the absolute value of the correlation coefficient (r). Latent variables included: former misconduct, FM; reporting obligation, RO; shared responsibility, SR; unacceptable misconduct, UM; written policies, WP. Higher-order variables: last-year misconduct, LYM; threat, THR.

Furthermore, latent variable “Reporting Obligation” RO positively correlates with latent variable SR (r = 0.298), as well as with the higher-order variable THR (r = 0.271). In contrast, the latent variable RO has a weak negative correlation (r = -0.243) with the higher-order variable LYM.

The latent variable “Written Policy” (WP) positively correlates (r = 0.296) with the higher-order variable THR. And vice versa, the latent variable “Written Policy” (WP) negatively correlates with the higher-order variable LYM (r = -0.160) and the latent variable “Former Misconduct” (FM) (r = -0.156).

General linear model

The results of the General Linear Model (GLM) for each dependent variable are summarized as Additional File 4. All models included Institution, Gender, Education Level, Seniority, and Number of Supervised PhD Candidates as fixed factors; estimated marginal means were used for additional pairwise comparison with Bonferroni correction.

The analysis revealed that “Institutional affiliation” remained a significant predictor ($p < 0{,}05$) for 5 out of 7 latent variables, namely FM, SR, WP, THR and LYM. However, the effect sizes for the institution factor were generally small (ω^2 varying from 0.007 to 0.024), suggesting that while the research environment plays a role, it does not fully account for the variance in the scores.

"Education level in research ethics" showed significant effect on FM ($F = 3.485$, $p = 0.031$, $\omega^2 = 0.007$), SR ($F = 3.863$, $p = 0.021$, $\omega2 = 0.009$), WP ($F = 9.06$, $p = 0$, $\omega2 = 0.024$), THR ($F = 6.723$, $p = 0.001$, $\omega2 = 0.017$) and LYM ($F = 3.961$, $p = 0.019$, $\omega2 = 0.009$). In estimated marginal means pairwise comparison, participants with highest education in research ethics refer less FM and LYM and logically higher scores of SR, WP and THR.

"Seniority", i.e. years spent in research, proved to be a significant predictor of FM (F = 3.158, p = 0.024, ω2 = 0.01), RO (F = 3.304, p = 0.02, ω2 = 0.01) and WP (F = 4.226, p = 0.006, ω2 = 0.014). As could be seen, effect sizes (ω^2) are really low and pairwise comparisons stress little bit different picture – senior researchers point more on SR, RO and WP than their younger colleagues. Nevertheless, "Number of Supervised PhD Candidates" did not yield significant results at all.

In case of "Gender", SR (F = 8.003, p = 0.005, ω2 = 0.01) is affected, as women insist on shared responsibility more than men.

Discussion

Our data provide the first systematic description of research integrity in biomedical research in 10 countries of Central and Eastern Europe. As already pointed out by other authors, the main limitation of the research on this topic is the methodological heterogeneity, which usually does not allow a correct comparison and interpretation of data collected by different research groups[22].

The first critical point of this study was the completion rate, which ranged from 34.15 % to 2.32 % of target group members in a given institution or institutional unit. Although this rate seems low, it is fully comparable to those published by other researchers for online surveys on research integrity. For example, the nationwide study in Japan reported a response rate of 60.6 %, but this value is related to the ratio of accessed to completed questionnaires[13]. If the authors of this study were to use a methodology comparable to ours, their reaction rate would be 4.03% and their completion rate would be 2.44 %[13]. Similarly, the completion rate in the Dutch study would be 29.3 % if it referred to all members of the target group invited to participate in the study[34]. In addition, the Croatian research group reported a response rate of 8 % to 15 % for their online survey[23], which is also fully comparable to our study.

A second limitation of our study is the presence of self-selection bias. We believe that the willingness to respond to inquiries about research ethics and scientific misconduct is the most potent source of self-selection bias. In other words, invited individuals who understood the importance of research integrity were more likely to be willing to spend time on such a survey. Conversely, those who do not adhere to the principles of responsible conduct of research are more likely to ignore such surveys, which may lead to underreported results, especially regarding personal involvement in scientific misconduct, willingness to report problematic behavior, and willingness to accept responsibility. This limitation of surveys on scientific misconduct has already been addressed in previous important studies that have pointed out the underestimated frequency of scientific misconduct[1,15].

The demographic characteristics of our target population across biomedical research institutions in 10 Central and Eastern European countries revealed certain peculiarities compared to other similar studies. As expected, since our study was not conducted solely in medical schools and our participants were more diverse, we found that only a quarter of our respondents worked in clinical research, while three-quarters worked in basic or other research areas (Fig. 1c). In contrast, the studies performed solely in medical schools reported a clear prevalence of participants from clinical research area[10,23,25–27] with the exception of Ph.D. students at the Karolinska Institutet, where basic research also strongly prevailed[27]. Nevertheless, our ratio of researchers with and without a background in health professions is almost equal (Fig. 1b), indicating an interdisciplinary approach to biomedical research in general. Furthermore, the fact that only one-tenth of respondents completed their previous studies in another country (Fig. 1d) indicates that the international affordability of biomedicine-related education is still low in the countries included in our survey.

In terms of gender issues, the slight predominance of females in our group of respondents (Fig. 1a) aligns with the aforementioned studies conducted in other European countries[23,25–27,35] while other international studies have reported an inverse ratio[18,36]. In any case, these differences among regions are to be expected. Furthermore, general linear models revealed in our group of respondents that women place more importance on shared responsibility than men do (Additional File 4). Unfortunately, there is limited data available on gender in relation to scientific integrity. However, our findings are in accordance with an analysis of gender differences among authors of retracted papers in biomedical sciences, which revealed the differences in women representation in relation to the retraction reason[37,38]. Nevertheless, gender itself does not affect scientific integrity as such[29].

The majority of our respondents were experienced researchers, as approximately 60 % of them reported having been in their careers for more than 10 years (Fig. 1e). This aspect, in particular, makes our study valuable for mapping the state of research integrity in the field in the participating countries. Not surprisingly, seniority, in terms of the number of years spent in research, is a significant predictor of former misconduct, according to general linear model results. Our data also showed that these senior, experienced researchers emphasize written policies, reporting obligations, and shared responsibility – i.e., cultivating a favorable research environment. These findings contradict the recently published results of a 10-year follow-up study from Norway showing that attitudes and behaviors related to research integrity did not significantly change over the course of a professional career[30]. However, this discrepancy can be easily explained by difference in the length of the professional career of these two cohorts: Hofmann and colleagues analyzed a period from the first year of Ph.D. studies to 10 years later, i.e., early-career researchers only. In contrast, our cohort showed that the aforementioned change is associated with later phases of the scientific career. Furthermore, our results on seniority are in accordance with the recent findings by Brooker and Allum[39].

However, about half of the respondents reported having no experience supervising students (Fig. 1f), which is probably due to the varying levels of involvement of institutions or their units in student research training programs. It should also be emphasized that our focus on active researchers who have employee status at their home institution limits the comparability of our results with those of other studies performed by Hofman and colleagues using the same questionnaire, because their studies were predominantly aimed at doctoral students[23,25–27]. Only the Croatian study provided separate results for supervisors[23], which we used to compare with our results in the discussion below.

The data on the research environment showed that only one-third of the respondents reported receiving education in science ethics during their undergraduate or doctoral studies (Fig. 2a). This situation may contrast sharply with practices in Scandinavian countries, where the attendance of specialized science ethics courses or lectures during undergraduate studies varied from 59 % to 76 % among different groups of respondents[25–27]. Furthermore, the general linear models revealed that the highest level of education in science ethics is associated with less reporting of both former and recent misconduct, as well as with a greater insistence on written policies and shared responsibility. Respondents with the highest level of education in science ethics also recognize problematic practices as a threat to their field of research. These results clearly confirm that education in science ethics is an essential part of favorable research environment that fosters research integrity. The importance of this education has been analyzed in depth repeatedly[40–42], emphasizing the need for this training, especially during Ph.D. studies[43,44].

It should also be highlighted that 10 % of our respondents said that they did not remember whether or not they received such education in science ethics when asked about one or another type of study (Fig. 2a). This information is alarming because, as mentioned before, systematic education in scientific ethics is a crucial part of a favorable research environment. Forgetting this education by its recipients (or forgetting its absence) indicates that something went wrong in this regard. Therefore, we must emphasize the importance of improving this aspect of research integrity for all countries participating in our survey. In light of this, the possible role of research integrity supervisors should be of special interest[45].

Fewer than half of our respondents reported the existence of written institutional policies on sensitive issues of research integrity at their home institutions (Fig. 2b). These policies most frequently addressed plagiarism, followed by rules regarding research funds (Fig. 2b). Moreover, the uncertainty about the existence of such written policies, claimed by one-third to one-half of respondents (Fig. 2b), should be understood as warning information for institutional managements. And as our correlation matrix of latent variables revealed, these written institutional policies are another important aspect of the research environment aimed at preventing scientific misconduct: a negative correlation was found between the existence of written policies and the reporting of recent or former experiences with misconduct (Table 6,Fig. 7). The importance of various types of policies, including institutional ones, for fostering of research integrity and preventing scientific misconduct was reported repeatedly[46–48] and these conclusions are fully consistent with our findings.

The mapping of real experiences with scientific misconduct was divided into two periods: recent experiences, i.e., experiences within the last 12 months (Fig. 3) and former experiences, i.e., experiences within the last three years (Fig. 4). Although these two periods were mapped using different types of questions, the results obtained showed significant positive correlation between the latent variable “Former Misconduct” and the higher-order variable “L12” (Fig. 7), as will be discussed in detail below.

Furthermore, the recent experience was evaluated based on the level of personal participation (Fig. 3). As expected, the most frequently reported experience was awareness of another person’s involvement in scientific misconduct, especially in terms of misleading results presentation (Fig. 3c). Meanwhile, personal active or passive engagement was stated only rarely; however, misleading data presentation was also the most frequently indicated type of misconduct in these subcategories (Fig. 3a-b). These findings are in accordance with older meta-analysis reporting very similar frequencies to ours both for personal involvement and awareness of another person’s misconduct[1]. If compared with data from other studies using the same questionnaire, the Croatian study found the data fabrication or falsification as the most frequently reported types of misconduct, when the answers of the supervisors only were taken into account due to their comparability with our group of respondents[23].

In contrast, the most frequently reported issue of recently experienced unethical pressure was related to authorship and reaches about 30 % (Fig. 3d). This finding is comparable with data from three Scandinavian universities showing that 20 % of respondents experienced pressure related to authorship inclusion or ordering in the last 12 months[27]. It should also be noted that, although personal engagement in scientific misconduct was reported to be very sporadic, up to one-tenth of the respondents mentioned a recent confrontation or uncertainty about a confrontation regarding the consequences of misconduct (Fig. 3e).

The scaled-response questions mapping former experiences with misconduct (Fig. 4) showed that QRP issues, especially gifted authorship, N-hacking, and retention of results, were the most frequently indicated. In contrast, serious misconduct, i.e., FFP issues, were sporadically reported. This is partly contradictory to the findings from the Netherlands, where 10 % of respondents working in life and medical sciences admitted to being involved in fabrication or falsification for the same time period, i.e., within the last three years before the survey[17]. Nevertheless, the types of misconduct that were mentioned the least were undisclosed conflicts of interest and hidden funders in publications. In other words, both were related to transparency. In any case, our data revealed significantly lower frequencies of QRP compared to the meta-analysis by Fanelli, in which personal involvement was 34 %, and awareness of another person’s misconduct was 72 %[1]. This difference could be explained by several factors. One factor is the discrepancy in how QRP was defined in our study compared to those by Fanelli and colleagues[1]. The second factor is the 15-year time difference between these studies. During this period, awareness of research integrity requirements became widespread in the scientific community, which should have led to a decline in the frequency of QRP. However, the recent survey from the Netherlands revealed that 55 % of respondents working in life and medical sciences were involved in any form of frequent QRP[17]. Regarding gift authorship, a recent study of early-career researchers in five European countries (Denmark, Hungary, Ireland, Portugal, and Switzerland) showed that 34 % of them actively engaged in this practice[35]. These data are in accordance with our findings and the very same frequency of gift authorship was also found in the Scandinavian study[27].

Data on personal acceptability of various forms of misconduct (Fig. 5a) also showed that most respondents clearly recognized all practices within the FFP category as unacceptable. Conversely, removing outliers and p-hacking seems to be more or less acceptable practices for about 20 % of respondents. Nevertheless, the most alarming information from this question concerns the possibility of data manipulation in the project proposal: this practice was considered more or less acceptable by 44 % of respondents, while 34 % considered it more or less unacceptable. The almost identical results on data manipulation in project proposals were achieved among Croatian supervisors[23]. This suggests that approximately half of the project proposals may be based on intentionally manipulated data. Such a finding raises questions about the meaningfulness of funding biomedical research in general.

Furthermore, our data showed that three-quarters of respondents found whistleblowing more or less acceptable when the wrongdoer was not specified in detail. However, when the wrongdoer is a colleague/peer or supervisor/PI, the acceptability of whistleblowing decreases to 60 % (Fig. 5b). These data are similar to the findings obtained in the Croatian study for the group of supervisors. However, the researchers noted a higher willingness for whistleblowing if the wrongdoer was a PI than a coworker[23]. Another large international study of eight European leading research universities on the reporting of misconduct (in which the authors intentionally omitted the term “whistleblowing”) showed that the willingness to report a problematic behavior is higher among senior researchers and is mainly related to the FFP rather than the QRP[49]. Furthermore, these results align with our previous findings regarding the relationship between seniority and reporting obligations, as described above.

The data also showed limited willingness to share the consequences of one typical FFP practice: data fabrication. To share the blame in such a situation is fully or mostly unacceptable for 35 % of respondents and to share the punishment is fully or mostly unacceptable for 40 % of them (Fig. 5b). Again, very similar results were obtained among Croatian supervisors[23].

The final section of the questionnaire focused on personal perceptions of scientific misconduct in biomedicine (Fig. 6). Respondents estimate that authorship misconduct is the most frequent type of misconduct in the field. However, it is considered to have the lowest risk of detection and the least severe consequences if detected. As expected, the pattern of responses is inverse for severe misconduct. These findings also correspond to those obtained in the Croatian study among the supervisors[23] and with a previous study on scientific misconduct at medical research centers in Belgium[50].

Nevertheless, the unique findings of our study came from the latent variable model showing the correlations between latent and higher-order variables, which reflect important domains in the A4L questionnaire (Fig. 7). The correlations found depicted the importance of the overall research environment regarding scientific integrity, which is apparently interconnected with the incidence of various forms of misconduct as experienced recently or in the past. This is indicated by the significant negative correlation between recently experienced misconduct (L12) and viewing the misconduct as a real threat to the research in the field of biomedicine (higher-order variable “Threat"). Similarly, the negative correlation between “Threat” and the latent variable “Former Misconduct” suggests a similar trend over the longer time period.

In more detail, the researchers, for whom any form of misconduct is unacceptable, understood the obligation to report such behavior whenever it is detected, including misconduct committed by superiors. This can be seen from positive correlation between latent variables “Unacceptable Misconduct” and “Reporting Obligations”. Similarly, those who understood any form of misconduct as unacceptable, are ready to accept the shared responsibility of all authors for published articles, as shown from positive correlation between these two latent variables. The same relationship is indicated by the inverse negative correlation between each of these two latent variables and previous experience with misconduct (the latent variable “Former Misconduct”): those who have actively or passively experienced misconduct are less willing to report it to the responsible official persons or take responsibility for the problematic behavior.

Furthermore, the significant positive correlation between the recent (higher-order variable L12) and the past (latent variable “Former Misconduct”) shows that the incidence of misconduct persists over time at research institutions. In other words, this is not a sporadic or accidental phenomenon.

Another interesting correlation involves written policies addressing various misconduct issues. The existence of such a written policy (regardless of the topic covered) correlates positively with the latent variable “Shared Responsibility” and with any recent experience with scientific misconduct. In this context, the negative correlation between the existence of a written policy (WP) and recent experience with misconduct (L12) suggests that institutions with an active approach to preventing misconduct have experienced lower incidence of misconduct during the last year. These findings are fully consistent with other recent studies that reported the importance of favorable research environment as a key factor in strengthening research integrity[28,29,39]. Furthermore, the role of overall research culture in improving quality of research and in fostering research integrity was also highlighted in relevant literature[18,51].

Conclusion

Finally, we would like to emphasize that upholding scientific integrity is not just a matter of individual attitudes; it is a cornerstone of trustworthy science and a functioning research community. As biomedical research increasingly influences healthcare, technological advancements, and related policies, the consequences of scientific misconduct in this field become more severe. Especially cases of FFP not only hinder scientific progress but also undermine public confidence in research institutions. However, QRP must also be considered seriously because many surveys, including ours, reveal it as much more frequent than FFP. Therefore, QRP erodes the reliability of published research studies, resulting in devastating consequences similar to those of FFP. Therefore, prevention measures must address the broader context in which research is conducted, rather than focusing solely on the issue of FFP.

Our study using a latent variable model yielded unique results clearly showing that cultivating a healthy research environment is essential to reducing the risk of scientific misconduct. Universities and research organizations should actively foster an research environment that values honesty, truthfulness, transparency, collaboration, and integrity more than mere output metrics. This includes providing education on responsible research conduct, implementing fair and supportive mentorship practices, and ensuring that written policies are meaningfully integrated into daily institutional life.

Data availability

Data are provided within the manuscript or the additional files. All other data related to this study are available upon request from the corresponding author, Renata Veselska, at veselska@mail.muni.cz

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Author contributions
RV, EG and AB conceptualized this study; AB, RV and JS adapted the questionnaire; RV, EG and JS organized the invitation to participate in this survey; A4L FG2 consortium members distributed the links to the questionnaires and provided information on the target group size; JS administered the questionnaire and collect raw data; JS and RV analyze and interpret the data; RV wrote the manuscript; JS, EG and AB critically revise the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics
This study was conducted in accordance with international research guidelines and national laws. The intent to conduct this survey was presented to the responsible research ethics committees (RECs) at the participating research institutions and each REC was provided with the full version of the A4L questionnaire along with a cover letter. As this type of research is subject to different types of ethical evaluation according to specific national legislation, our survey was either subjected to ethical review and approved to be conducted (Croatia, Hungary, Slovenia) or a statement was issued that ethical review was not required (Bulgaria, Czechia, Latvia, Lithuania, Poland, Romania, Slovakia). The following statements were issued by the institutional RECs, listed in alphabetical order by country name:
Statement No. 3379/14.10.22 issued by the Rector of Medical University – Sofia, Bulgaria

Approval No. 380-59-10106-22-111/148 issued by the Ethics Committee, School of Medicine, University of Zagreb, Croatia
Statement No. EKV-LS-2022-007 issued by the Masaryk University Research Ethics Committee, Czechia
Approval No. 212/2022 issued by the Semmelweis University University Ethics Committee, Hungary
Statement No. 01/22 issued by the Latvian Institute of Organic Synthesis Biomedicine Research Ethics Committee, Latvia
Statement No. 2022-10-18 issued by the Vilnius Regional Biomedical Research Ethics Committee, Lithuania
Statement No. RNN/261/22/KE issued by the Medical University of Lodz Bioethics Committee, Poland
Statement No. PO-35-F-03b issued by the Research Ethics Committee, University of Medicine and Pharmacy "Carol Davila", Romania
Statement No. 10.10.2022 issued by the Ethics Committee of Biomedical Research Center of the Slovak Academy of Sciences, Slovakia
Approval No. 0120-428/2022/3 issued by the Medical Ethics Committee, Ministry of Health, Slovenia
No personal data of human subjects were collected during the research and respondents participated in the survey as anonymous employees of their home institutions and not as identifiable individuals. Under these conditions, no written informed consent to participate was obtained from the respondents. Nevertheless, respondents were informed about the questionnaire in detail on the introductory screen of the survey. After reading the information, they provided implicit consent to participate by clicking the "Start the Survey" button.

Additional information

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Alliance for Life Focus Group 2: Research Ethics and Research Integrity

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