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Multi-institutional authorship in genetics and high-energy physics

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HIGHLIGHTS

- The annual percentages of multi-institutional authors (MIA) are increasing.
- Most MIA in genetics are affiliated with two or more universities.
- Most MIA in high-energy physics (HEP) are affiliated with two types of institutions.
- The academic impact of HEP articles by MIA is greater than that of other articles.

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ABSTRACT

This study investigated the characteristics of multi-institutional authors and the academic impact of their articles in the fields of genetics and high-energy physics. The findings showed that the percentage of articles written by multi-institutional authors (87.3%) and the percentage of multi-institutional authors (27.8%) in genetics were higher than those (50.4% articles and 17.1% authors) in high-energy physics. Increasing trends were observed in the annual percentages of multi-institutional authors and their articles between 2008 and 2013 in both fields. Most multi-institutional authors were affiliated with two institutions. However, most multi-institutional authors in genetics were affiliated with two or more universities, whereas most multi-institutional authors in high-energy physics were affiliated with at least one university and one research institution. The academic impact of articles by multi-institutional authors was observed to be greater than that of other articles in high-energy physics (12.6 vs. 7.62 mean citations per article), and the opposite was observed in genetics (73.14 vs. 75.63 mean citations per article).

1. Introduction

Multi-institutional authors refer to authors affiliated with more than one institution (e.g., two universities). Different institutions share the same researchers. Although multi-institutional authorship is not a new concept, studies analyzing coauthorship usually neglect the existence of multi-institutional authorship and do not process data related to multi-institutional authorship, implying the assumption that a single author cannot be affiliated with two or more unions or institutions. This is primarily because researchers cannot identify multi-institutional authors solely based on bibliographic records of research outputs collected from databases, because no links have been built between author affiliations and author names. For example, the Web of Science (WoS) database did not match each author's name to his or her institution before

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2007 [1]. Under such circumstances, verifying links between institution names and author names through human review based on full texts of publications is a laborious task, which explains why bibliometric studies on coauthorship tend to overlook the issue of multi-institutional authorship.

Coauthorship analyses have been extensively applied to explore the different levels of research collaborations based on coauthored publications. At the institutional level of coauthorship analyses, multi-institutional authors contribute to the research output of at least two institutions when they publish research results. Institutional academic performance benefits from multi-institutional authorship if each institution is assigned full credit. However, multi-institutional authorship results in disputes regarding institutional collaboration. Determining whether multi-institutional authorship is equal to institutional collaborations is a controversial topic.

Institutional collaboration is commonly defined as authors being affiliated with at least two institutions in a coauthored article [2–4]. More than one author and at least two institutions are the requirements for coauthored articles generated from interinstitutional collaborations. Katz and Martin [5] described that multi-institutional authorship represents formal institutional collaboration, because different institutions have agreed to share the same author. However, multi-institutional authorship includes articles written by a single author affiliated with two or more institutions, indicating that multi-institutional authorship may not involve collaboration between researchers. Furthermore, a single-authored article with two addresses does not always denote multi-institutional authorship. Some authors provide their home addresses in addition to the institution addresses, indicating that multi-institutional authorship is not necessarily equivalent to coauthorship.

Notably, research collaborations have become a common approach to generate research output and continue to increase. With an increase in the proportion of coauthored articles, whether the percentages of multi-institutional authors and their articles have also increased over time remain uncertain. Multi-institutional authorship is not a typical type of research collaboration. If multi-institutional authorship was regarded as a type of research collaboration, it would be encouraged by institutions because their research performance would be enhanced. However, an increase in the number of articles with multi-institutional authorship would distort authorship-analysis-based data on institutional research performance and collaboration trends. As such, fields with high proportions of studies with multi-institutional authorship and increasing trends in multi-institutional authorship should be investigated in terms of the impact of multi-institutional authorship on the measurement of research performance. Fields where multi-institutional authorship studies are commonly conducted must be identified.

Given the lack of studies related to multi-institutional authorship, this study was conducted to facilitate the understanding of the development of multi-institutional authorship and the characteristics of articles by multi-institutional authors. To obtain results related to multi-institutional authorship that could be referenced for future research, the selected fields needed to have high proportions of multi-institutional authorship studies. Therefore, genetics and high-energy physics were selected as the academic fields in this study, because Katz and Martin [5] highlighted that a higher percentage of articles were written by multi-institutional authors in biomedicine and physics than in other disciplines. Genetics and high-energy physics are respectively subfields of biomedicine and physics, making them suitable candidates for academic fields for this study. The following four research questions were addressed in this study:

1. Is there an increasing trend in the annual proportion of multi-institutional authors?
2. What is the distribution of institutions associated with multi-institutional authors?
3. What is the distribution of combinations of institution types based on affiliation information for multi-institutional authors?
4. Do articles by multi-institutional authors have greater academic impact than other articles?

2. Literature review

Multi-institutional authors refer to authors affiliated with more than one institution. The existence of such authors can lead to the establishment of interinstitutional collaborations involving two or more institutions. When authors are affiliated with multiple institutions, they may provide several author affiliations. Some authors become multi-institutional authors because they have part-time jobs, are visiting scholars, or are working for an institution temporarily [5]. Multi-institutional authorship may be adopted to seek external research resources or enhance personal earnings [6]. This type of connection is not equivalent to typical interinstitutional collaboration involving at least two authors from different institutions. No consensus has been reached regarding the question of whether multi-institutional authorship is one type of interinstitutional collaboration [5]. Institutional academic performance benefits from multi-institutional authorship because a single author's publications contribute to the performance of more than one institution. Evidently, the relationship between authors and institutions can be complicated.

Katz and Martin [5] investigated the percentage of multi-institutional-authored articles published between 1981 and 1990 by reviewing Science Citation Index papers, and they identified clinical medicine as the field with the highest percentage of articles by multi-institutional authors by year (40%–50%), followed by biomedicine and physics (10%–15%), biology and earth and space sciences (5%–10%), and chemistry, mathematics, and engineering (each with less than 5%). However, researchers are rarely concerned with multi-institutional authorship when conducting coauthorship analyses. For example, although increasing trends in multi-institutional collaborations have been identified in medicine [7], no study has analyzed multi-institutional authorship in this field. The main reason for this observation may be that coauthorship

is common practice in medicine; therefore, the possibility of overlooking single-authored articles by a multi-institutional author is lower.

Few studies have focused on multi-institutional authorship. Katz and Hicks [8] identified differences in academic impact among various types of research collaboration and noticed a number of single-authored articles with two or more institutional addresses. West et al. [9] applied the Eigenfactor score to rank the scholarly outputs of authors, institutions, and countries and assigned credit to every institution with which a multi-institutional author was affiliated. Kumar and Jan [1] investigated research collaborations in business and management in Malaysia between 1980 and 2010, and they used the first and most recent affiliations of authors with multiple affiliations to form a network of institutional collaboration. Hottenrott and Lawson [6] investigated multi-institutional authorship in three fields in three countries based on articles published between 2008 and 2014. They identified multi-institutional authorship in 5.81%–10.18%, 5.69%–9.23%, and 6.98%–8.19% of studies in biology, chemistry, and engineering, respectively. An increasing trend of multi-institutional authorship was observed. Authors engaging in multi-institutional authorship tended to publish articles in journals with high impact factors.

Although numerous studies have reported that coauthored articles have greater influence than single-authored articles [10,11], and even that the number of authors contribute to the increase in influence [11], the number of authors has not been proven to be a strong factor contributing to the increase in the number of citations received [12–16]. Inconsistent findings were also reported for the relationship between the number of countries and the influence of publications among disciplines [17]. Katz and Hicks [8] identified that articles by multiple authors from various countries had greater average influence than articles by multiple authors from a single country and single-authored articles. Gazni and Didegah [18] investigated the influence of various collaboration patterns on the citation impact of Harvard University publications based on the articles published by researchers affiliated with Harvard University in the WoS between 2000 and 2009. The frequency of normalized citations per coauthored paper was higher than that per single-authored paper in all 22 examined fields. The highest number of publications in each field was published through interinstitutional collaboration and was a result of collaboration between domestic researchers. Publications by multiple institutions receive more citations, and publications involving more overseas collaborators are not frequently cited.

Although some researchers have identified a relationship between the number of authors and institutions and the academic impact of publications, the academic impact of articles by multi-institutional authors has rarely been investigated [6]. Therefore, this study aimed to fill the research gap by exploring whether articles by multi-institutional authors have a greater academic impact than other articles.

3. Methodology

3.1. Data collection

We extended our previous study on hyperauthorship in genetics and high-energy physics by selecting the same two journals from each field: *American Journal of Human Genetics* and *Nature Genetics* from genetics, and *Astroparticle Physics* and *European Physical Journal C* from high-energy physics. Journal candidates were considered from journals listed for the two subject categories of "genetics and heredity" and "physics, particles and fields" in the 2013 edition of Journal Citation Reports. Because a considerable number of articles were published in journals from the two fields during the study period, only the two selected journals were analyzed for each field. A total of 102,524 genetics articles were published between 2008 and 2013; at least 2347 genetics articles needed to be included in the present study to achieve a 95% confidence level with a 2% margin of error. The same requirements for determining the sample size of high-energy physics articles were adopted. The lowest possible number of high-energy physics sample articles was 2316. These sample sizes assisted us in estimating that at least two journals were required in each field.

To ensure that the selected journals were representative samples, journals were selected based on impact factor and the percentage of hyperauthored articles in 2013, both of which needed to be high. The bibliographic records of articles published between 2008 and 2013 were collected from the WoS database on July 31, 2014. No connections were built between author names and institution names by WoS before 2007. Thus, multi-institutional authors could not be identified based on these bibliographic records. Therefore, articles published in the four selected journals before 2007 were not analyzed in this study. In addition, 14 high-energy physics articles did not provide connections between author names and institution names and were thus excluded. A total of 2377 genetics and 2670 high-energy physics research articles formed the sample dataset.

3.2. Data processing and analysis

Identifying multi-institutional authors was the most time-consuming task in data processing. This was because the bibliographic records related to author names and affiliations were exported from the Web of Science database. The bibliographic records of an article contained all affiliations for all authors, with individual affiliations listed once and authors affiliated with the same specific institution placed underneath this reference. This format led to multi-institutional author names being listed at least twice. One author name could be linked to multiple institutional names. Therefore, a given multi-institutional author and his or her affiliated institutions in each article had to be manually examined. In particular, most articles were coauthored by a large number of authors affiliated with several institutions.

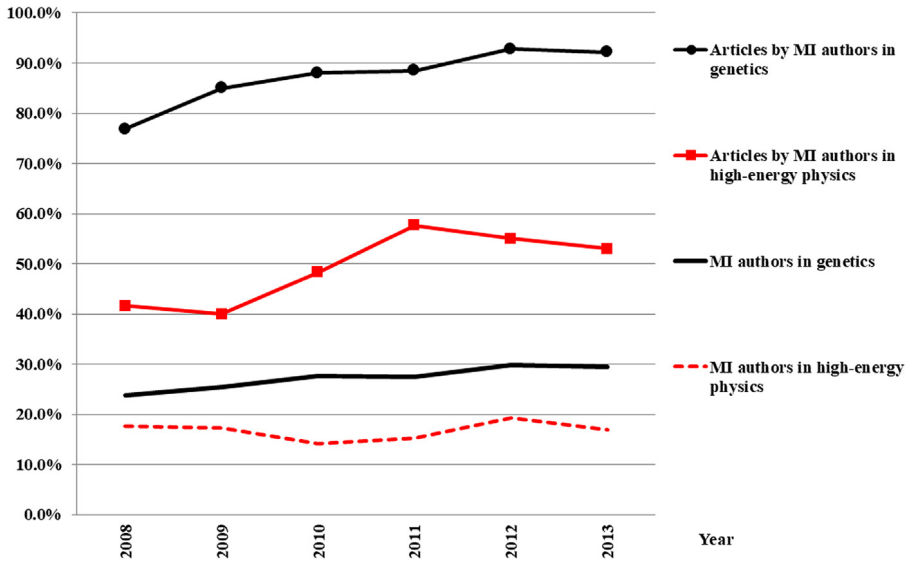

Fig. 1. Changes in annual percentages of multi-institutional authors and their articles.

All articles in this study were divided into two groups: multi-institutional-authored articles and other articles. An author affiliated with two or more institutions was defined as a multi-institutional author, and an article by at least one multi-institutional author was classified as a multi-institutional-authored article. Multi-institutional-authored articles consisted of single-authored and coauthored articles and were divided into two groups: international and domestic articles. When a multi-institutional author was affiliated with at least one overseas institution, the corresponding article was classified as an international multi-institutional article.

To identify the distribution of institutions by type based on multi-institutional-authored articles, five types were devised referring to the studies of Leydesdorff [19] and Park and Leydesdorff [20]: universities; industries; research institutions; hospitals, including hospitals affiliated with universities; and other. If the specific type of institution could not be identified from the institution name, additional information related to the institution was obtained through the institution's website or other websites. Address information was used to identify the number of institutions with which an author was affiliated.

4. Results

4.1. Trends of multi-institutional authors and their articles

Most articles published in the aforementioned two genetics and two high-energy physics journals between 2008 and 2013 were coauthored articles (95.4% and 83.9%, respectively). Among the 2377 genetics articles, approximately 87.3% were written by multi-institutional authors, a proportion substantially higher than that of 50.4% in the 2,670 high-energy physics articles, revealing a higher percentage of single-authored articles by multi-institutional authors in high-energy physics. In addition, Pearson's chi-squared test confirmed that a significant statistical difference existed in the distribution of articles by multi-institutional authors between genetics and high-energy physics ($p < 0.05$). Fig. 1 shows the increasing trends in the annual proportions of multi-institutional-authored articles in genetics and high-energy physics, indicating that the authors in these fields tended to be affiliated with more than one institution. Based on the cumulative numbers of authors for each article, 27.8% of the 61,872 genetics authors were multi-institutional, a proportion higher than that of 17.1% for 277,768 high-energy physics authors. Fig. 1 shows the slightly increasing trends in the annual percentages of multi-institutional authors in the two fields.

4.2. Comparison of characteristics of articles by multi-institutional and other articles

Table 1 shows the changes in the average numbers of authors, institutions, and countries between articles by multi-institutional authors and other articles in high-energy physics and genetics. Independent t-test results confirmed that significant differences existed in the average numbers of authors, institutions, and countries between multi-institutional-authored articles and other articles in both fields. In addition, the range and standard deviation revealed large differences in the scatter of observations between multi-institutional-authored articles and other articles in both fields.

Table 1
Comparison of means between multi-institutional-authored articles and other articles.

	High-energy physics				Genetics			
	MIA articles	Other articles	*t*	*p*	MIA articles	Other articles	*t*	*p*
No. of articles	1,345	1,325			2,075	302		
Average no. of countries	6.17	1.30	17.723	0.000*	4.02	1.84	18.907	0.000*
Range	1–43	1–21			1–32	1–12		
SE	0.273	0.30			0.081	0.082		
SD	10.022	1.076			3.712	1.420		
Average no. of institutions	224.39	4.18	11.500	0.000*	12.43	3.55	20.288	0.000*
Range	2–3943	1–355			1–197	1–54		
SE	20.881	0.501			0.369	0.235		
SD	765.797	18.245			16.816	4.081		
Average no. of authors	209.92	4.19	11.545	0.000*	28.23	10.88	17.85	0.000*
Range	1–3171	1–368			1–436	1–118		
SE	17.812	0.506			0.786	0.572		
SD	653.246	18.432			35.783	9.947		

Note: MIA articles,multi-institutional-authored articles; SE, standard error; SD, standard deviation.
* $p < 0.05$.

Table 2
Distribution of institution number.

No. of institutions	Genetics		High-energy physics	
	No. of authors	%	No. of authors	%
2	12,734	74.15%	39,537	83.04%
3	3,168	18.45%	5,957	12.51%
4	956	5.57%	1,093	2.30%
5	234	1.36%	868	1.82%
6	63	0.37%	53	0.11%
7	16	0.09%	16	0.03%
8	0	0.00%	17	0.04%
9	0	0.00%	7	0.01%
10	2	0.01%	11	0.02%
11	0	0.00%	11	0.02%
12	0	0.00%	3	0.01%
13	0	0.00%	6	0.01%
14	1	0.01%	4	0.01%
15	0	0.00%	3	0.01%
16	0	0.00%	27	0.06%
Total	17,174	100.00%	47,613	100.00%

4.3. Numbers of institutions with which multi-institutional authors were affiliated

Table 2 shows the ranges of institutions with which multi-institutional authors were affiliated. Genetics and high-energy physics multi-institutional authors were affiliated with up to 14 and 16 institutions, respectively. Most multi-institutional authors were affiliated with two or three institutions. Approximately 74.15% of genetics multi-institutional authors were affiliated with two institutions, a proportion lower than that of approximately 83.04% for high-energy physics multi-institutional authors. The average number of institutions per multi-institutional author was 2.3 in high-energy physics, which was slightly lower than that of 2.4 in genetics. However, a significant difference was observed in the distribution of multi-institutional authors affiliated with two or more institutions ($p < 0.05$).

4.4. Institution combinations by type

Table 3 lists the distribution of institution combination types with which multi-institutional authors were affiliated in both fields. In genetics, 24 institutional combinations were identified, consisting of five combinations of a single type of institution, ten of two types of institutions, seven of three types of institutions, and two of four types of institutions. Most multi-institutional authors (78.0%) were primarily affiliated with three institutional combinations. Those affiliated with two or more universities accounted for the largest proportion (37.2%), followed by those affiliated with at least one university and one hospital (20.5%) and those affiliated with at least one university and one research institution (20.3%). In high-energy physics, 16 institutional combinations were identified. Authors affiliated with at least one university and one research institution (65.2%) accounted for the largest proportion, followed by those affiliated with at least two universities (27.2%).

Table 3
Institution types with which multi-institutional authors were affiliated.

No.	Institution type	Genetics		High-energy physics	
		No. of authors	%	No. of authors	%
1	University-university	6,386	**37.2**%	12,944	**27.2**%
2	University-hospital	3,514	**20.5**%	3	0.0%
3	University-research institute	3,492	**20.3**%	31,043	**65.2**%
4	Hospital-hospital	834	4.9%	0	0.0%
5	Research institute-research institute	633	3.7%	3,005	6.3%
6	Research institute-company	591	3.4%	8	0.0%
7	University-research institute-hospital	543	3.2%	6	0.0%
8	University-other	384	2.2%	105	0.2%
9	University-company	252	1.5%	30	0.1%
10	Hospital-other	162	0.9%	0	0.0%
11	Research institute-other	126	0.7%	126	0.3%
12	Other-other	63	0.4%	19	0.0%
13	University-research institute-other	62	0.4%	23	0.0%
14	University-hospital-other	39	0.2%	0	0.0%
15	Company-research institute	37	0.2%	14	0.0%
16	Company-company	16	0.1%	281	0.6%
17	University-company-hospital	8	0.0%	0	0.0%
18	Research institute-hospital-other	8	0.0%	0	0.0%
19	Company-hospital	7	0.0%	0	0.0%
20	University-research institute-hospital-other	6	0.0%	0	0.0%
21	University-company-research institute	5	0.0%	3	0.0%
22	Company-other	3	0.0%	1	0.0%
23	University-company-other	2	0.0%	2	0.0%
24	University-company-hospital-other	1	0.0%	0	0.0%
	Total	17,174	100.0%	47,613	100.0%

4.5. Multi-institutional authors and their articles by country

Most multi-institutional authors were affiliated with institutions within the same country. International authors accounted for 8.9% of all multi-institutional authors in genetics, a proportion lower than that of 15.7% in high-energy physics. Fig. 2 shows the annual percentages of international multi-institutional authors in both fields. The annual percentages of articles by such authors in both fields exhibited a slightly decreasing trend. Although international multi-institutional authors were not the dominant type, most multi-institutional-authored articles were written by at least one international author. The percentage of such articles ranged between 69.9% and 74.9% in high-energy physics, which was slightly lower than that in genetics (73.9%–78.9%).

Table 4 lists the 20 countries with the highest percentages of multi-institutional authors. In genetics, 30.6% of all multi-institutional authors were from the United States. The remaining 19 countries each accounted for 9.1% or less of multi-institutional authors. Similar findings were observed in high-energy physics. The highest percentage of multi-institutional authors (19.3%) was from Italy, followed by the United States (13.0%). The remaining 18 countries each accounted for 8.6% or less. Differences were observed in the percentages of international multi-institutional authors between genetics and high-energy physics. Each country within the top 20 contributed a higher percentage of international multi-institutional authors in genetics than in high-energy physics.

4.6. Academic impact of articles by multi-institutional authors

Table 5 shows that the average number of citations received per article by multi-institutional authors in genetics was 73.14, which was slightly lower than that (75.63) per article by other authors. The sign test revealed no significant differences in the average number of citations between these two article types ($p = 0.644 > 0.05$); however, a significant difference was observed in the average numbers of citations between the two article types in high-energy physics ($p = 0.000 < 0.05$). The average number of citations received per article by multi-institutional authors was 12.61, which was higher than that (7.62) received per article by other authors. In addition, the difference in the distribution of citations received by multi-institutional-authored and non-multi-institutional-authored articles in genetics was greater than that in high-energy physics.

Fig. 3 shows the differences in the average numbers of citations between the two article types by year and field. A decreasing trend was observed in the annual average number of citations between the two article types in genetics. In addition, a strong decreasing trend was observed for the annual average number of citations received in the two article types. A comparison of the two article types in high-energy physics revealed a small difference in the annual average number of citations but no drastic changes.

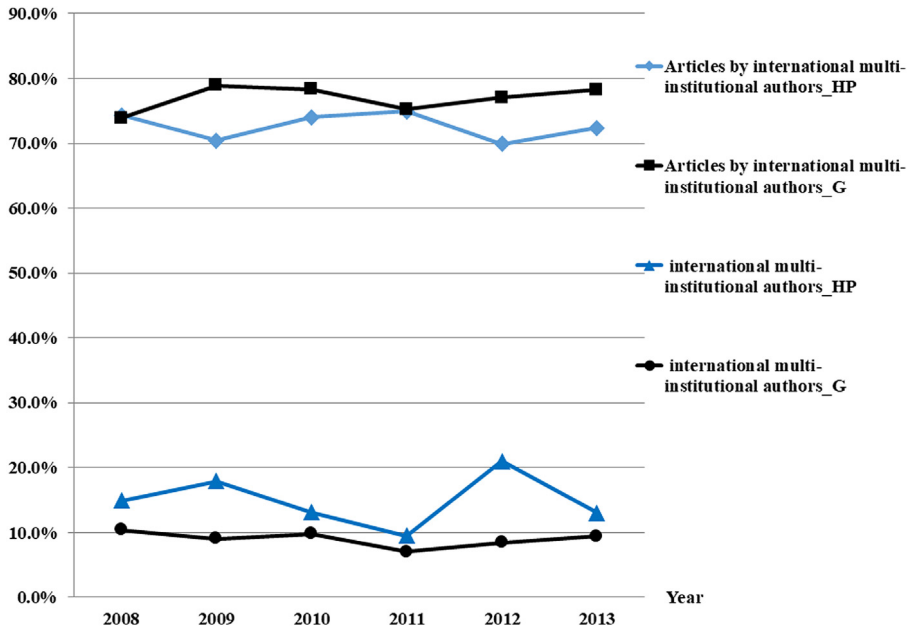

Fig. 2. Changes in annual percentages of international multi-institutional authors and their articles.

Table 4
Top 20 countries with the highest percentages of multi-institutional authors.

Genetics					High-energy physics				
Rank	Country	MI authors (a)	MI authors (b)	IMI authors (c)	Rank	Country	MI authors (a)	MI authors (b)	IMI authors (c)
1	USA	30.6%	31.0%	13.3%	1	Italy	19.3%	67.6%	40.4%
2	China	9.1%	35.2%	11.8%	2	USA	13.0%	31.5%	72.6%
3	England	9.0%	25.7%	27.6%	3	Germany	8.6%	29.7%	79.0%
4	France	7.4%	47.4%	8.5%	4	France	7.6%	45.0%	61.2%
5	Germany	5.9%	26.5%	25.3%	5	Switzerland	5.0%	34.7%	96.1%
6	Netherlands	4.8%	32.7%	14.2%	6	Japan	4.1%	37.8%	82.8%
7	Canada	4.2%	41.8%	13.1%	7	England	4.1%	29.8%	95.6%
8	Australia	3.3%	36.1%	17.4%	8	Spain	4.0%	43.9%	60.5%
9	Italy	2.6%	24.9%	22.7%	9	Russia	3.8%	28.4%	83.7%
10	Spain	2.2%	35.8%	13.7%	10	China	2.5%	31.7%	50.0%
11	Finland	2.1%	53.4%	20.5%	11	Netherlands	2.5%	55.1%	56.4%
12	Belgium	1.9%	41.3%	14.1%	12	Canada	2.4%	46.1%	91.0%
13	Japan	1.8%	12.6%	10.2%	13	Sweden	1.7%	51.3%	65.9%
14	Israel	1.5%	38.2%	10.4%	14	Portugal	1.7%	59.1%	74.2%
15	Sweden	1.4%	28.2%	39.2%	15	Poland	1.5%	40.7%	81.9%
16	Switzerland	1.4%	38.8%	36.4%	16	Argentina	1.1%	60.7%	58.1%
17	Singapore	1.0%	37.7%	36.9%	17	Morocco	1.1%	65.2%	96.0%
18	Scotland	1.0%	24.3%	17.8%	18	Republic	1.1%	35.5%	91.5%
19	Denmark	1.0%	31.6%	31.0%	19	Turkey	0.9%	43.4%	91.2%
20	Norway	0.9%	49.2%	18.1%	20	Brazil	0.9%	24.0%	67.3%

Note: (a) refers to the percentage of multi-institutional authors in a specific country to all such authors. (b) refers to the percentage of multi-institutional authors in a specific country to all authors in the same country. (c) refers to the percentage of international multi-institutional authors in a specific country to all multi-institutional authors in the same country.

5. Discussion and conclusion

This study investigated multi-institutional authorship in genetics and high-energy physics from 2008 to 2013. Four major differences were observed in the characteristics of multi-institutional-authored and other articles. First, the prevalence of articles by multi-institutional authors was observed in genetics and high-energy physics; however, the percentage of articles by multi-institutional authors was much higher in genetics than in high-energy physics (87.3% and 50.4%, respectively). The percentages of multi-institutional authors in both fields were higher than those reported by Katz and Martin [5] and by Hottenrott and Lawson [6]. Furthermore, this study confirmed the increasing trends in the annual proportions of articles by multi-institutional authors in both fields. The disciplinary culture with large teams and reliance on advanced equipment

Table 5
Comparison between average numbers of citations in articles by multi-institutional authors and other authors.

Statistical characteristics	Genetics	High-energy physics
No. of MIA articles	2,075	1,345
Range of citations received by MIA articles	0–1194	0–437
Average no. of citations per MIA article	73.14	12.61
SE	2.34	0.677
SD	106.608	24.842
No. of non-MIA articles	302	1,325
Range of citations received by non-MIA articles	0–744	0–184
Average no. of citation per non-MIA article	76.63	7.62
SE	5.611	0.398
SD	97.502	14.498
P value	0.644	0.000*

Note: MIA articles, multi-institutional-authored articles; SE, standard error; SD, standard deviation.
* $p < 0.05$.

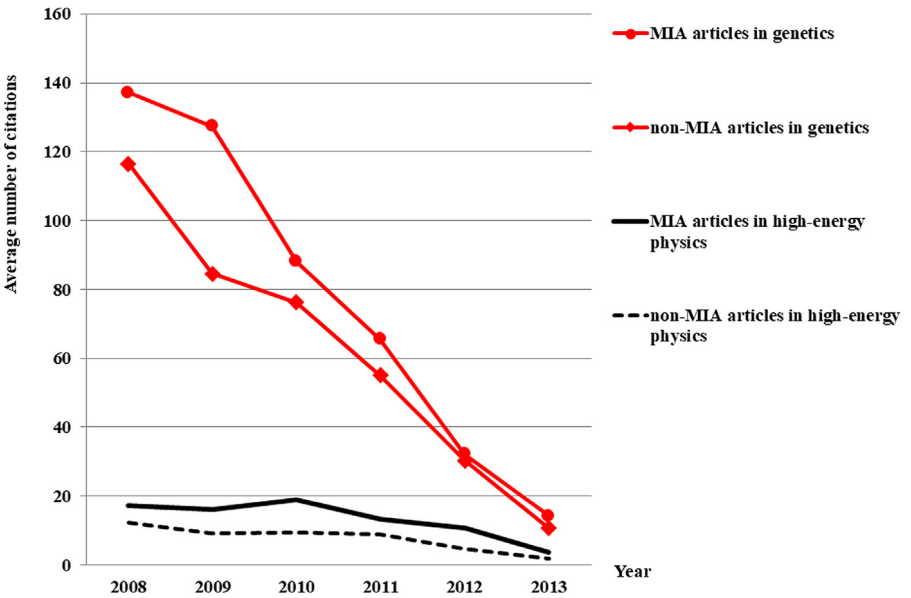

Fig. 3. Average numbers of citations by year and article type.

may explain the high proportion of articles by multi-institutional authors in genetics and high-energy physics. Large-scale research supported by advanced facilities and high levels of funding is common in experiment-oriented disciplines [21]. Authors engaging in multi-institutional authorship can gain research resources from multiple institutions and thus obtain higher levels of funding than can other authors.

Second, the percentage of multi-institutional authors was higher in genetics than in high-energy physics (27.8% and 17.1%, respectively). The proportions of studies with multi-institutional authorship in both fields were higher than those in biology, chemistry, and engineering, as observed by Hottenrott and Lawson [6]. Although increasing trends were observed for the percentage of articles by multi-institutional authors in both fields, regarding the annual percentages of multi-institutional authors, an increasing trend was only observed in genetics. Regarding the percentage of multi-institutional authors, such authors were not the dominant type, which was expected in this study.

Third, numerous combinations of institution types were found in this study. Various dominant combinations of institution types were observed in genetics and high-energy physics. Most multi-institutional authors in genetics were affiliated with more than one university, and most multi-institutional authors in high-energy physics were affiliated with at least one university and one research institution. In addition, 20.5% of multi-institutional authors in genetics were affiliated with at least one university and one hospital, whereas only three such authors were found in high-energy physics. Hospitals were expected to be a dominant institution type in genetics, because genetics is a subfield of medical science. According to Hottenrott and Lawson [6], inconsistent findings in the same field were observed in different countries. Most authors engaging in multi-institutional authorship in biology, chemistry, and engineering in Japan and Germany were affiliated with

higher education institutions and research institutes, whereas most such authors in three fields in the United Kingdom were affiliated with two or more higher education institutions. Although university–industry collaboration has been encouraged in science and technology for decades, only a slight increasing trend has been previously revealed [22]. In this study, a similar trend was also observed. The percentages of multi-institutional authors affiliated with universities and companies were limited in both fields.

Fourth, in high-energy physics, articles by multi-institutional authors had a greater academic impact (mean citations per article) than other articles (12.61 vs. 7.62), and a significant difference was observed between the two article types. In genetics, the opposite was observed (73.14 vs. 75.63). Therefore, the findings of this study were not completely supported by the results that the number of institutions involved in a paper have a positive effect on the number of citations [12,13,23], indicating that a publication's academic impact is a complicated issue. A publication's academic impact is affected by numerous factors [1–14,24,25]. No consistent findings are available that can be generally applied to all disciplines.

Regarding similarities in the characteristics of multi-institutional authorship between high-energy physics and genetics, three major findings were revealed. First, articles by multi-institutional authors had higher average numbers of authors, institutions, and countries than other articles. However, such characteristics did not guarantee their great academic impact. Second, most multi-institutional authors were affiliated with two or three institutions, which was expected in this study. No significant differences were observed in the distribution of the number of institutions. Notably, certain institutions do not allow their employees to be affiliated with another institution. However, the findings of this study related to the number of affiliated institutions of authors indicated that institutions that prohibiting researchers from being affiliated with other institutions is not prevalent. Motivations for obtaining multi-institutional authorship such as seeking additional research resources and improving visibility may explain its growth [6]. Otherwise, we were unable to determine why few multi-institutional authors were affiliated with an unusual number of institutions. The 87 multi-institutional authors affiliated with more than seven institutions in high-energy physics (0.2% of all multi-institutional authors in this study) were affiliated with multiple universities and research institutions. Third, most multi-institutional authors were not affiliated with institutions in more than one country. Decreasing trends in the annual percentages of international multi-institutional authors were observed in both fields.

The limitation of this study is that only four journals were analyzed because of the large number of available genetics and high-energy physics articles and because identifying articles by multi-institutional authors is a highly laborious task. Therefore, although 5054 articles were analyzed, the results of this study do not adequately represent the fields of genetics and high-energy physics. However, the average numbers of multi-institutional-authored articles in genetics and high-energy physics were estimated to be lower than the data yielded by this study, because the four selected journals have a higher percentage of articles by multi-institutional authors than both fields on a whole.

Despite the limitation, the findings of this study represent a crucial contribution. Multi-institutional authorship has existed for many years; however, few related empirical studies have been conducted. This study is the first to investigate multi-institutional authorship in high-energy physics and genetics and focused on the basic characteristics of multi-institutional authors and their articles. Several findings facilitate a comprehensive understanding of the characteristics of articles by multi-institutional authors in two fields. The increasing trends in the annual percentages of multi-institutional authors and their articles indicate that additional studies should analyze multi-institutional authorship. This study revealed that most authors engaging in multi-institutional authorship were affiliated with two institutions: mainly two universities or one university and one research institution. Hence, some universities and research institutions could benefit from multi-institutional authorship, especially those that value academic ranking. This finding implies that multi-institutional authorship could help institutions to enhance their visibility by encouraging researchers to become affiliated with other institutions. Articles by authors engaging in multi-institutional affect the research performance of institutions in terms of research productivity. Furthermore, researchers benefit from this type of research collaboration through improvements in their research performance obtained by extending their research resources and social networks. Although the findings of this study do not completely support that the academic impact of articles by multi-institutional authors is higher than that of other articles, high-energy physics articles by multi-institutional authors that have been proven to have a greater academic impact would likely be welcomed by journal editors and could encourage high-energy physics researchers to seek multi-institutional authorship. In particular, institutional research productivity in fields with higher proportions of multi-institutional authors is often overestimated, implying that the academic impact of multi-institutional authorship should be considered when measuring institutional research productivity.

Because of a gap in the literature on multi-institutional authorship and the limitations of the present study, future should conduct additional surveys on cross-discipline multi-institutional authorship. To enable research findings to represent the characteristics of specific disciplines, sample articles should be drawn from a high number of journals. Furthermore, prior to this study, the factors leading to the increasing trend of multi-institutional authors were not widely known. The factors resulting in authors being multi-institutional and the factors affecting the academic impact of articles by multi-institutional authors should also be analyzed. Regarding fields with relatively high proportions of multi-institutional authorship and articles, authorship analyses must consider that the results are affected by articles with multi-institutional authorship. In particular, attitudes held toward multi-institutional authorship in various fields could facilitate or hinder the growth of multi-institutional authorship. Perspectives on multi-institutional authorship in various fields should also be a point of focus in related research.

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