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The Contributions of Authors to Multiauthored Biomedical Research Papers.

[Original Contributions]

Shapiro, David W. MD, JD; Wenger, Neil S. MD, MPH; Shapiro, Martin F. MD, PhD

From the Divisions of General Internal Medicine, Veterans Affairs Medical Center (Dr D. Shapiro) and UCLA Medical Center (Drs Wenger and M. Shapiro), Los Angeles, Calif. Dr D. Shapiro is now with the Division of General Internal Medicine, San Francisco (Calif) General Hospital.

The authors indicated in parentheses made substantial contributions to the following tasks of research: initial conception (M.F.S.); design (D.W.S., N.S.W., M.F.S.); provision of resources (D.W.S.); collection of data (D.W.S.); analysis and interpretation of data (D.W.S., M.F.S.); writing and revision of paper (D.W.S., N.S.W., M.F.S.).

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Reprint requests to 130 Washington Ave, Palo Alto, CA 94301-3945 (Dr D. Shapiro).

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Abstract

Objective: To determine the contributions of each author to multiauthored biomedical research papers.

Design: Mailed, self-administered survey.

Participants: A total of 184 first authors from a consecutive sample of 200 papers with four or more authors published in 10 leading biomedical journals.

Main Outcome Measures: First authors' ratings of which authors had made substantial contributions to the following: initial conception of the study, design of the study, provision of needed resources, collection of data, analysis and interpretation of data, and writing the first draft of the paper or revising drafts for important intellectual content.

Results: The contributions of nonfirst authors varied greatly within and among papers. Even second and last authors--though they generally contributed more than other nonfirst authors--were markedly inconsistent in the extent and pattern of their contributions. Time spent on the research differed among authors by orders of magnitude. An appreciable number of authors made few or no substantial contributions to the research.

Conclusions: The nature and extent of contributions of nonfirst authors to biomedical research reported in multiauthored papers cannot reliably be discerned (or discounted) by authorship or order of authors. The two core purposes of scientific authorship--to confer credit and denote responsibility for research--are not adequately being met by these authorship practices.

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The meaning of scientific authorship is under intense scrutiny and debate. Controversies about authorship are being aired in congressional hearings, research institutions, laboratories, scientific journals, and mass media. At issue are standards for authorship, responsibility for fraudulent or invalid research, authorship requirements for promotion and tenure, and the allocation and order of authorship on individual papers. Underlying these controversies are different beliefs about what authorship should mean and assumptions about what authorship in fact represents.

Scientific papers could be published anonymously: in principle, the results of scientific research should not depend on who performed the work. In practice, the signing of scientific papers by their authors serves two fundamental purposes: it confers credit and denotes responsibility for the research. Authorship credit is important to researchers because it helps them gain promotions, grants, and the approbation of professional societies and their peers. By accepting responsibility for the research they publish, authors certify the integrity of their work. To editors, peer reviewers, and readers of scientific reports, a paper's credibility and importance depend in part on who performed the work. It is essential to users of scientific information that authors believe in and certify the validity of their published work.

These two core purposes of authorship may not be well served today. When research was conducted primarily by solo investigators, credit and responsibility for the work were definitively communicated by authorship. Since then, the average number of authors per scientific paper has been steadily rising [1,2,3,4]. A century ago, in the journal that has become The New England Journal of Medicine, more than 98% of papers were written by a single author; now, fewer than 5% are [5]. The mean number of authors per paper in The New England Journal of Medicine increased from four in 1975 to more than six in 1989 [6]. The number of papers listed on individual researchers' curricula vitae also seems to have increased, with some prolific investigators publishing literally hundreds of papers [7,8,9,10].

These trends may be due in part to the increasingly collaborative and interdisciplinary nature of research. But many believe that authorship is being granted for smaller and smaller contributions. In recent well-publicized cases of scientific fraud, some authors of the papers were so minimally involved in the research that they did not detect its falsity [11,12]. Some of them actually used their lack of participation to justify why they should not be held responsible for the

contents of the false papers they had authored (although they apparently were willing to receive credit for the papers before their validity was questioned) [11]. Other anecdotal evidence suggests that "honorary authorship"--not justified by contributions to the research--is not uncommon [13].

Whatever the cause, greater numbers of coinvestigators make it more difficult for investigators to ensure the validity of their coauthors' contributions and for readers to discern each author's contributions from the fact and order of authorship. Rising numbers of authors per paper (and papers per investigator) impair the ability of academic promotions committees, funding organizations, and others to assess the research contributions and ability of investigators. Authorship inflation may both reflect and contribute to increasing publication pressure, which has been cited as important in the genesis of scientific fraud [14].

Debates about authorship would be greatly improved if the current patterns of contributions of authors to research were known, but this information does not exist. The purpose of this study is to determine the contributions of the authors of a cross section of the best multiauthored biomedical research conducted in the United States.

METHODS

We sampled 20 papers from each of five leading basic science journals (American Journal of Physiology, Cell, Journal of Biological Chemistry, Nature, and Science) and 20 clinical research articles from each of five leading medical journals (Annals of Internal Medicine, Circulation, Gastroenterology, The Journal of the American Medical Association, and The New England Journal of Medicine). Full-length original biomedical research papers from each journal were considered consecutively for inclusion in the study, beginning from the same arbitrary date in 1989 (not identified herein to protect the confidentiality of responses) and continuing back in time through earlier issues until 20 papers from each journal were included in the study. The study was limited to papers with four or more authors because much of the debate about authorship has focused on problems thought to be associated with multiple authorship. In addition, our a priori hypothesis was that greater diversity in authors' contributions would be found in papers with more authors. A total of 226 papers in the series of consecutive papers considered for the study were ineligible because they had three or fewer authors, of which 173 were basic science papers. In this series, approximately two thirds of basic science and one third of clinical research papers had three or fewer authors.

Among papers with four or more authors, individual authors were disqualified from the sample if they did not have a US address or if they were already included in the study on another paper. Three authors from each paper were surveyed (only the first authors' responses are reported herein). Papers were excluded if the first author was rejected from the sample, if any author was affiliated with the investigators' institutions (UCLA and its affiliates), or if three authors did not qualify to be surveyed. These criteria led to the exclusion of 179 papers, most because of non-US addresses.

The 200 papers included in the study had a total of 1176 authors, with a median of five authors per paper.

A self-administered questionnaire was developed to obtain information about the contributions of each author to specific elements of the research presented in the paper, time spent overall on the research, and demographics. Based on literature review and interviews with researchers, the important elements or tasks of a typical research project were conceptualized as follows: (a) initial conception, (b) design of the study, (c) provision of needed resources, (d) collection of data, (e) analysis and interpretation of data, and (f) writing the first draft of the paper or revising drafts for important intellectual content.

The exact wording of the questions on these six main tasks can be found in Table 1. The task of provision of resources was broken down into separate questions about the provision of funding, chemical or biological materials, research subjects, access to study site or secondary data, laboratory equipment or personnel, or other resources. Respondents were also asked to identify substantial contributions to the provision of patient care, performance of a pilot or feasibility study, and obtaining of necessary institutional or other approvals.

Table 1.—Wording of Questions on the Six Major Tasks of Research

1. Who made a substantial contribution to the initial conception of the research reported in this paper?
2. For each resource listed below, mark an "X" in the box under each person who made a substantial contribution to providing the resource. (If a resource was not used in this study, leave that row blank.)

   a. funding; *b.* chemical or biological materials (eg, drugs, assays, probes, cell lines, etc); *c.* research subjects, or substances obtained directly from them; *d.* access to study site or to secondary (preexisting) data or records; *e.* lab, equipment, personnel, technical advice or assistance; *f.* other resources (specify _____).
3. Who made a substantial contribution to designing this study to answer the research questions, including designing data collection methods, forms, surveys, or interventions?
4. Who made a substantial contribution to collecting data (from all sources and by all methods, including performing laboratory or medical procedures or interventions, or managing or supervising data collection)?
5. Who made a substantial contribution to analyzing and interpreting data (including statistical analysis, coding, cleaning, or checking data)?
6. Who made a substantial contribution to

   a. writing the first draft of this paper; *b.* revising drafts for important intellectual content (includ-

Table 1. Wording of Questions on the Six Major Tasks of Research

Using a grid format with tasks listed in the left-hand column and authors listed across the top of the page, respondents were asked to check off which authors made a substantial contribution to these tasks of the research. Respondents were instructed not to guess, but to indicate only those contributions of which they were reasonably sure. Although a paper may be based on prior published work, respondents were instructed to confine their answers to the work reported in this particular paper.

After completing this section of the questionnaire, respondents were asked to rate their knowledge of the contributions of each of the other authors to the research reported in the paper as excellent, good, fair, poor, or none. Responses concerning any given author were used only if the respondent's knowledge of that author's contributions was good or excellent.

The questionnaire (which is available from the authors on request) took from 8 to 20 minutes to complete. It was mailed to the authors in our sample along with an introductory cover letter written by a former editor of a major biomedical journal, a letter from the investigators explaining the study, a copy of the first page of the article in question (including the abstract), and a $5 cash incentive. The surveyed authors were promised that their responses would be anonymous and confidential. To avoid cross contamination of answers, mailings to authors of the same paper at the same institution were staggered by at least 2 weeks, and all authors were instructed to answer based solely on their own knowledge and not to discuss the questionnaire with anyone. A second copy of the questionnaire and an accompanying letter from the investigators were mailed to nonrespondents 4 weeks after the first.

Responses were analyzed using statistical software (CRUNCH Version 4, Crunch Software Corporation, Oakland, Calif). Significance testing was two tailed, and chi squared (chi^2) tests were used unless otherwise stated. Throughout, the term "middle author" is used to denote authors other than the first, second, or last.

RESULTS

Response and Usable Sample

Usable questionnaires were returned by 184 first authors (92%). Their median age was 36 years and they had published a median of 15 papers. Fifteen percent were women and 27% were head of a laboratory, group, division, or department. Forty-nine percent were faculty; 40% were postdoctoral trainees, fellows, house staff, or students; 3% worked in private companies; and 7% worked for government or other nonprofit organizations. Nonresponding first authors were not significantly different from respondents in academic title or position, and nonrespondents' papers did not differ significantly from respondents' in the numbers of authors per paper (Mann-Whitney test) Table 2.

Table 2.—Number of Authors in Papers Whose First Authors Responded to the Survey*

No. of Authors in Paper	No. (%) of Papers
4	50 (27)
5	48 (26)
6	34 (18)
7	20 (11)
8	12 (7)
9	11 (6)
>9	9 (5)
Total	184 (100)

*Of the 16 papers whose first authors did not respond, four had four authors; three each had five, six, and seven authors; one had eight authors; and two had more than nine authors.

Table 2. Number of Authors in Papers Whose First Authors Responded to the Survey

The 184 first-author respondents had good or excellent knowledge of the contributions of 1014 (93%) of the 1091 authors of their papers. Information concerning the remaining 77 authors was not included in the analysis.

Contributions to the Research

Authors contributed most often to the provision of needed resources (68%) and least often to the initial conception of the study (42%) Table 3, column 1). About half of the authors made substantial contributions to study design, data collection, analysis and interpretation of data, and writing or revision (not the same half for each task).

Table 3.—First Authors' Assessments of the Contributions of Authors to Specific Tasks

Task*	All Authors Together (n=1014), %	First Authors (n=184), %	Second Authors (n=175), %	Middle Authors (n=479), %	Last Authors (n=176), %
Initial conception	42	90	34	19	64
Design	47	97	41	24	61
Provision of resources	68	72	62	62	85
Data collection	54	89	62	45	34
Analysis and interpretation of data	52	98	56	30	61
Writing and revision	57	100	55	33	80
Total No. of tasks contributed to					
0 or 1	24	0	17	42	10
2 or 3	32	3	46	40	29
4, 5, or 6	43	97	37	18	61

*For each task, $P<.0001$ for differences among author positions.

Table 3. First Authors' Assessments of the Contributions of Authors to Specific Tasks

The types of contributions of authors varied greatly by authorship position Table 3, columns 2 through 5). For every element of the research except the provision of resources, nearly all first authors made a substantial contribution. Second authors' rates of contributions were substantially lower than those of first authors, but they contributed a majority of the time to each task except conception and design. By contrast, one third or fewer of middle authors (those not listed first, second, or last) made contributions to any one task except for provision of resources (62%) and data collection (45%). They were the least frequent contributors to the intellectual tasks of initial conception, design, analysis and interpretation, and writing or revision. Last authors' pattern of contributions was intermediate between that of first authors and of second authors, except that last authors were the most frequent contributors of resources (85%) and the least likely to have collected data (34%).

The total number of tasks to which each author contributed varied greatly, with 24% contributing to no or one task, 33% to two or three, and 43% to four, five, or six tasks. This, too, was related to author position Table 2. The median number of elements of research to which authors contributed substantially was six for first authors, three for second authors, two for middle authors, and four for last authors, but authorship position other than first did not convey level of participation with any consistency. For example, approximately as many middle authors made substantial contributions to five or six of the major elements of research (9%) as made substantial contributions to none of them (11%), and while 16% of last authors contributed in all six areas, 10% contributed in none or one. Large discrepancies typically occurred within as well as among papers. Even the pattern of relative contributions within papers was not consistent: in 157 papers (85%), at least one author had made more contributions than another author listed before him or her.

Papers also differed greatly in the mean number of contributions made by each author: for 26% of papers, authors contributed to an average of fewer than three of the six tasks listed in Table 3, while in 21% of papers they made contributions in an average of more than four of these

areas. In part, this was related to the number of authors of the paper: papers with more authors tended to have lower mean numbers of contributions per author. Authors contributed to an average of more than three of the six areas in 73% of papers with four or five authors, for example, compared with 38% of papers with more than five authors (P<.0001).

The first authors' estimates reveal large disparities in the number of hours spent directly on the research by different authors Table 4, both within and among papers. Time spent ranged from none to more than 1000 hours, and as many authors spent 5 or fewer hours on the research as spent more than 1000 hours (12% and 10%, respectively). First authors spent the most time, with 53% devoting more than 500 hours to the research, and second authors spent the next most time. Thirty-one percent of middle authors and 20% of last authors spent 10 hours or less. There were considerable disparities within authorship positions as well with, for example, similar proportions of second authors devoting 10 hours or less and more than 500 hours.

Table 4.—First Authors' Estimates of the Number of Hours Authors Spent Contributing Directly to the Research

No. of Hours*	All Authors Together (n=966), %	First Authors† (n=176), %	Second Authors† (n=187), %	Middle Authors† (n=456), %	Last Authors† (n=167), %
0-10	20	0	13	31	20
11-50	26	4	27	31	35
51-500	36	43	42	31	37
>500	18	53	18	7	8

*Hours categories are collapsed from the questionnaire's categories of 0, less than 1, 1 to 5, 6 to 10, 11 to 25, 26 to 50, 51 to 100, 101 to 500, 501 to 1000, and more than 1000.
†P<.0001 for differences among these four author positions.

Table 4. First Authors' Estimates of the Number of Hours Authors Spent Contributing Directly to the Research

The number of contributions made by an author was related to the time spent directly on the research, but the correlation was not perfect. Of the 80 authors who spent 1 to 5 hours on the research, for example, 18% made substantial contributions in no areas and 36% did so in one area, but 14% made substantial contributions to four or to five tasks in that short time. Similarly, of the 151 authors who spent from 51 to 100 hours, 25% contributed substantially in no or one area, while 27% did so in five or six areas. Even among the 33 authors who spent less than 1 hour directly on the research, 12 made a substantial contribution to one task and seven to more than one task (the majority of these contributions was to the provision of resources).

Authors Who Made Few Contributions to the Research

It is worthwhile to look more closely at those authors who made few contributions to the research, because they are most likely to exemplify the suspected dilution of the meaning of authorship. Sixty-two authors (6% of all authors) in 36 different papers were said to have made substantial contributions to none of the six major tasks of research. Twenty of them had made other contributions asked about separately in the survey: 17 had provided patient care needed for

the study (of whom 16 were middle authors), and three middle authors had performed a pilot or feasibility study but had not seen the main study through to its completion. Nine of them had spent from 51 to 500 hours contributing directly to the research. A majority were clinical faculty.

The remaining 42 authors who made no substantial contributions to any of the items listed in the survey had spent a median of 1 to 5 hours on the research. Although most (34) were middle authors, a few were second or last authors. Eight had left or joined the study while it was in progress. Eleven were heads of laboratories, groups, divisions, or departments where the research was conducted and often only contributed to the study by supervising the other authors.

A total of 184 authors (18% of all authors) contributed to only one main task of the research, of whom 79% were listed as middle authors, 14% as second authors, and 7% as last authors. Most of them contributed only to the provision of resources Table 5. The overwhelming majority of these contributions were of a technical nature (research subjects, chemical or biological materials, laboratory, equipment, technical assistance, access to the study site or data) rather than of grant support (which may be associated with more direct intellectual input). Almost one third of these resource providers also contributed to patient care. As might be expected, one fourth were heads of laboratories, groups, divisions, or departments.

Table 5.—Contributions of the 184 Authors Who Contributed to Only One Major Task

Task	No. (%) of Authors Contributing
Provision of resources*	106 (58)
Research subjects	46 (25)
Chemical or biological materials	35 (19)
Laboratory, equipment, technical assistance	29 (16)
Access to study site or to secondary data	16 (9)
Funding	14 (8)
Other	3 (2)
Collection of data	46 (25)
Writing and revision of paper	15 (8)
Analysis and interpretation of data	11 (6)
Initial conception	4 (2)
Design	2 (1)
Total	**184 (100)**

*Some authors provided more than one type of resource.

Table 5. Contributions of the 184 Authors Who Contributed to Only One Major Task

One fourth (46) of the single-contribution authors participated only in data collection. They were almost all postdoctorates, fellows, house staff, students, or paid technicians, and 13 of them had joined or left the study while it was in progress. The other 32 authors who made only one substantial contribution participated in one of the more intellectual tasks of writing or

revision, analysis and interpretation, initial conception, or design Table 5.

Two contributions were made by 170 authors (17% of all authors). Of these, 54 contributed only to provision of resources and collection of data. Overall, then, a total of 268 authors (26%) did not contribute substantially to their study's conception, design, analysis and interpretation, or writing or revision. These authors were found disproportionately in papers with greater numbers of authors (Mann-Whitney test, P<.0001).

Comparison of Clinical and Basic Science Papers

Authors of clinical papers tended to have made fewer substantial contributions than did authors of basic science papers. Thirty percent of clinical authors made no contributions to the more intellectual tasks of research (conception, design, analysis and interpretation, and writing or revision), compared with 21% of basic science authors (P<.01). Twenty-six percent of clinical authors contributed to fewer than two tasks vs 21% of basic science authors (P=.07). These differences are related to the greater number of authors typical of the clinical papers: clinical papers had a median of six authors while basic science papers had a median of five. When this is controlled for, the differences between clinical and basic science authors virtually disappear. For example, 42% of clinical middle authors had made fewer than two substantial contributions, compared with 41% of basic science middle authors. The only difference was for last authors: significantly more last authors of clinical than basic science papers contributed to fewer than two tasks (16% vs 3%; P<.05) or contributed at most to the collection of data and provision of resources (17% vs 2%; P<.01).

Reports of the 14 multicenter clinical trials in the sample had significantly more authors than did other papers (mean of 7.4 vs 5.8 authors per paper; Mann-Whitney test, P<.01). Their first authors had good or excellent knowledge of the contributions of only 83% of their coauthors, presumably because authors were located in multiple disparate sites (first authors of other types of papers had good or excellent knowledge of the contributions of 92% of their coauthors; P<.01). The authors of papers based on multicenter clinical trials spent significantly more hours contributing to the research (Mann-Whitney test, P<.05). They were more likely to have provided research subjects (P<.0001), performed patient care (P<.0001), and contributed to writing and revision of the paper (P<.001). Otherwise, the types and numbers of their contributions did not differ significantly from those of authors of other types of papers.

COMMENT

This study documents that authorship in multiauthored papers conveys little about the contributions made by any other than the first author. The contributions of nonfirst authors varied greatly within and among papers. Even second and last authors--though they generally contributed more than middle authors--were markedly inconsistent in the extent and pattern of their contributions. Time spent on the studies differed among authors by orders of magnitude. As a result, the nature or extent of contributions of authors cannot be reliably discerned by authorship or order of authorship. Neither can the contributions of authors be discounted by their authorship position, for many middle and last authors made extensive contributions to the research.

Even the relative contributions of authors within a paper are difficult to judge: contrary to a recent recommendation in JAMA, [15] the authors are not consistently listed in declining order of their contributions (at least in terms of the number of tasks they contributed to). Although the International Committee of Medical Journal Editors supports the inclusion of a footnote explaining how the order of authorship was determined [16], none of the papers in the study contained any notes concerning authorship (other than a list of the individual members of a collaborative group of investigators).

The contributions of a substantial number of authors seem minimal. According to the standards promulgated by the International Committee of Medical Journal Editors [17], only substantial contributions to the more intellectual tasks of research--conception, design, analysis and interpretation of data, and writing or revision of the paper--may be used to justify authorship. One third of nonfirst authors did not contribute to any of these tasks of research. This level of participation is not likely to permit authors to accept responsibility for or publicly defend the paper as a whole, although many believe these should be conditions of authorship [11,17,18,19,20].

Our study lends support to the belief that multiple authorship is associated with a dilution of the meaning of authorship. The authors of papers with fewer authors tended to have made more contributions than authors of papers with greater numbers of authors. Further research is necessary to determine whether this result can be extrapolated to papers with fewer than four authors, although even in papers with two or three authors some authors may have made few contributions.

Our study must be interpreted in light of several limitations. Some respondents may have inflated their own roles, and biases may have led some to overstate or understate the contributions of other authors. Contributions were assessed retrospectively rather than by contemporaneous observation or report. Hours spent on the research, in particular, may be rough estimates. Respondents may have differed in what they considered a "substantial" contribution. Finally, a failure to indicate that a given author made a substantial contribution to any particular task could represent either a definite statement that a substantial contribution was not made by that author or a lack of knowledge of that author's contributions to that task. In principle, however, a first author should know the contributions of the other authors to his or her work. In addition, respondents assessed their overall knowledge of each author's contributions after completing the contributions section of the questionnaire. Responses concerning individual authors were excluded from the analysis when the respondents' overall knowledge of their contributions was not good or excellent.

If authorship is to be based on contributions to the research, it may be helpful for each author's contributions to be identified explicitly in scientific papers [10,21,22]. An example of how this might be done is provided in this paper. The exercise of formally designating the contributions might improve decisions on authorship, because it would require that credit (and responsibility) explicitly be assigned for each part of the research. For example, persons involved with only part of a project may harbor misconceptions concerning the contributions of others to the research as a whole. It could be useful for misperceptions and disagreements to be uncovered

and resolved. It is clear from the high response rate to our survey that authorship is extremely important to researchers.

For those using authorship to make decisions concerning professional advancement or funding, clear identification of the contributions of authors would supply the missing information that is not now conveyed by the fact or order of authorship. Middle authors would receive proper credit for their contributions. There might also be less pressure to generate multiple papers from the same research so that several investigators can enjoy first-author credit [21].

In addition to specifying the contributions of authors in papers, it would be desirable for the scientific community to agree on and enforce minimum criteria for authorship. Many such criteria have been proposed, including the standards set for biomedical research by the International Committee of Medical Journal Editors [16]. The scientific community must make a serious effort to restore clearer meaning to authorship, or authorship's most essential purposes--assigning due credit and responsibility--may be lost.

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