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Levels of Citation of Nonhuman Animal Studies Conducted at a Canadian Research Hospital

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The publication of scientific articles that receive few or no citations raises questions of the appropriate use of resources as well as ethics. In the case of animal research, the ethics issue extends beyond human patients to nonhuman animals, as the research subjects them to pain and, typically, to death. This study is a citation analysis of animal research conducted at Toronto's Hospital for Sick Children (HSC). Of the 594 publications (1990 to 1995) on animal research by affiliates of HSC, 29% received fewer than 10 citations in a 10-year period. We compare the research history of 13 "best" and 13 "worst" HSC scientists. Worst researchers continue to do infrequently cited research. Recommendations indicate how institutions and researchers can become more effective and accountable.

Earlier research found that many experiments with animals in biomedical research received few or no citations in subsequent years (Dagg, 1999, 2000; Shapiro, 1998). The undertaking of such little-cited research raises questions of the appropriate use of resources because billions of dollars from government and charities world wide are spent annually on such research. It also raises questions of ethics; animal research typically exposes the subjects to pain, harm, and death.

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METHOD

We investigated the Hospital for Sick Children in Toronto (HSC), one of the largest institutions in Canada involved in animal research. This institution was selected because of its noted success in obtaining public research funds and the implied importance of its research efforts for human medical advances. In 2001–2002, external funding of research at HSC totaled more than $69 million from more than 150 sources, with by far the largest single contribution (30%) coming from the taxpayer-funded Canadian Institutes of Health Research, formerly the Medical Research Council of Canada (MRC). Given that a significant proportion of studies published by HSC-affiliated researchers describe animal experimentation—from 29% in 1995 to 33% in 2001 (Medline, 2002)—it is certain that a large proportion of HSC's overall research funding is used to finance animal research.

To carry out our research, biomedical articles from Medline, written by authors affiliated with the HSC, along with the keyword "animal," were analyzed for the period 1990 to 1995. After all review articles were removed from this data set, the citation count (up to summer 2002) for each of the remaining 594 papers was obtained from the Web of Science, care being taken to include in each number every slightly incorrect entry that seemed also to belong to it. If a paper did not appear under the first author's name, a search was conducted through the journal title to ensure that there were no errors in our tabulations. Although a citation search can be biased in some cases (May, 1997), it has been shown in various types of research articles to be the best indicator of quality (Callaham, Wears, & Weber, 2002; Lee, Schotland, Bacchetti, & Bero, 2002). We assume here that there is a positive correlation between the number of citations an experiment or paper receives and the advancement of medical research.

We analyzed the data in seven ways:

1. The number of citations earned by each of the 594 papers and the frequency with which these numbers occurred was tabulated to determine the general influence of the research.

2. To determine if the number of citations received by any one author was arbitrary, or if some authors routinely received notably more or fewer citations than others, the number of citations for the authors for each paper was tabulated. A separate analysis was then carried out for scientists who had published at least six papers.

3. From these data the names of the 13 "best" and 13 "worst" researchers were tabulated by certain criteria (see Appendix A). Each researcher is indicated by a letter for purposes of confidentiality. To determine if the "best" researchers were consistently better years later than the "worst" researchers, another data set was analyzed from Medline (2002) for the period 1998 to 2002, using the same criteria as the first data set (animal-related studies carried out by affiliates of HSC). Again, review articles and two popular articles were omitted. The number of citations for all the papers authored by the best and worst researchers was again tabulated.

4. Did these two groups of scientists receive similar funding? It is impossible to know the exact funding for each researcher, so money received from MRC, the largest funding source, about the time of the data set (1993 to 1997), was tabulated as a rough sample of their funding (Medical Research Council of Canada, 1993–1997).

5. The HSC Web site (www.sickkids.on.ca/research/) was accessed to determine how many of the 26 researchers were still affiliated with HSC in 2002.

6. The citation counts for all the 594 papers were analyzed to determine if those with more authors were more or less likely to garner citations than those with fewer authors.

7. The data were analyzed to determine if the least-cited researchers were much involved in teaching —coauthored papers and jointly carried out research with "apprentices" including summer students, graduate students, and postdoctoral fellows.

RESULTS

Frequencies of Citations

In our 6-year period of analysis (1990 to 1995), 1,044 researchers published 594 papers in each of which one or more authors had HSC affiliation. More papers received few rather than many citations, with a range of from 0 to 446 (see Figure 1). Twenty-two papers (4%) received no citations, 33 (6%) received over 100, and 174 (29%) received fewer than 10 in the approximately 9 years following their publication.

Citing of Researchers in 1990 to 1995 Data

The 13 best authors determined by the citation criteria applied are listed in Table 1, column 1, with the average number of citations they received for the 1990 to 1995 period (see columns 2 and 3).

Comparing the citations-for-research results of scientists for the 1990 to 1995 data set (columns 2 and 3) between Tables 1 and 2, some scientists generally obtained more citations for their work. The best researchers garnered 65.3 citations on average for their papers, whereas the worst researchers received on average 10.6, slightly more than one citation a year.

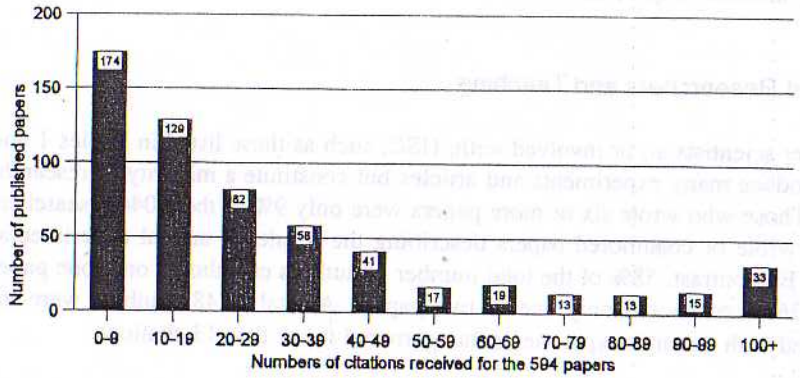

FIGURE 1 Frequency distributions of citations for animal-based research studies published by HSC-affiliated authors between 1990 and 1995.

TABLE 1
Authors With Best Record of Citations for Their Articles

	Citations for 1990 to 1995 Data		*Citations for 1998 to 2002 Data*	
Individual Researchers	*M*	*N*	*M*	*N*
A[a]	28.0	10	7.5	2
B[a]	84.9	9	33.0	11
C	52.6	14	—	—
D	76.7	10	—	—
E[a]	67.2	20	17.0	26
F	156.8	8	15.3	3
G[a]	56.8	30	11.5	29
H[a]	29.7	10	5.0	9
I	57.5	8	8.0	1
J	85.4	10	—	—
K	66.9	16	14.4	8
L	69.8	17	—	—
M[a]	40.9	8	53.0	1
Total		170		90
Average citations per paper	65.3		15.8	

[a]Funded by Medical Research Council of Canada.

Persistence of Difference

The citation record for 1998 to 2002 (see Tables 1 and 2, columns 4 and 5) data are not definitive because only a few years have passed since the papers were published; more time, most presumably, would garner more citations. However, the data are comparative and indicate that best authors continue to do well, receiving on average 15.8 citations per paper, whereas worst authors continue to do poorly, receiving on average only 3.1 citations per paper. In this second data set, four scientists from each group were no longer publishing research.

Comparative Funding for Best and Worst Authors

This comparison is a rough one because the exact funding of each scientist is not known. Not all received MRC funding. Each one may have received substantial grants from other sources, as noted in acknowledgments of up to 150 sources in their papers. In addition, all funding was not spent necessarily on animal research. However, it does show a gap between the two groups. Of HSC best researchers in Table 1, six ([a]) received MRC funding for the years 1993–1997, an average of $3.03 million (range = $1.27 million to $5.31 million). Of HSC worst

TABLE 2
Authors With Worst Record of Citations for Their Articles

	Citations for 1990 to 1995 Data		*Citations for 1998 to 2002 Data*	
Individual Researchers	*M*	*N*	*M*	*N*
N	5.5	10	—	—
O[a]	11.2	9	1.5	4
P	3.2	6	1.3	3
Q	5.8	8	2.0	1
R[a]	12.5	13	1.1	7
S	11.4	9	—	—
T[a]	10.9	7	3.0	5
U	6.5	8	—	
V[a]	13.8	11	5.5	8
W[a]	16.8	17	2.0	7
X[a]	16.2	13	5.7	3
Y	2.8	6	—	—
Z[a]	7.7	15	5.3	4
Total		132		42
Average citations per paper	10.6		3.1	

[a]Funded by Medical Research Council of Canada.

researchers in Table 2, seven (a) received MRC funding for the same years, an average of $1.21 million (range = $0.44 million to $2.47 million). The figures indicate that the most successful best researchers, excepting one, were well-funded by more than $2.5 million each. Worst researchers also were well-funded, with four receiving more than a million dollars each from MRC between 1993 and 1997. The best researchers were more prolific than the worst, publishing in total 170 compared to 132 papers between 1990 and 1995.

Continuing Research

Four of the best researchers are still doing research affiliated with HSC along with five of the worst researchers. Thus the research careers of these poorly cited scientists have not been curtailed despite the low citation results for their papers. Although the best researchers published 90 papers, the worst published only 42.

Multiple Authors Do Better Research

Using median averages to prevent skewing, it is evident that papers written by many authors are more likely to be cited (see Figure 2). Papers with six or more authors received up to three times as many citations on average as those by a single author. Probably because experiments involving many researchers are

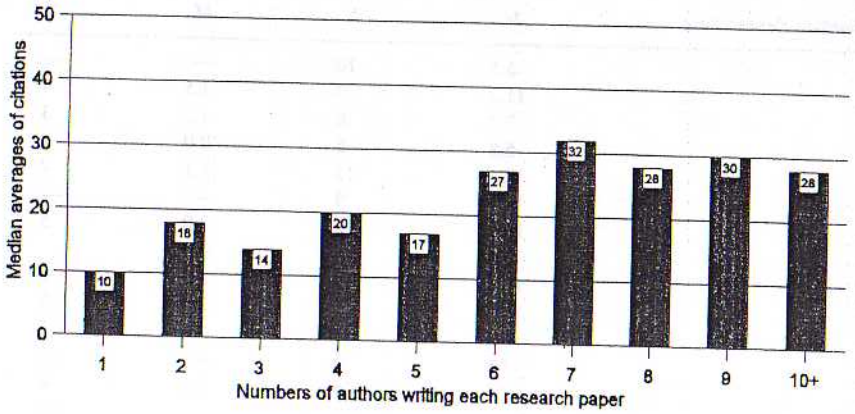

FIGURE 2 Median averages of citations received, organized by the number of researchers authoring each paper.

more carefully designed and thought out than those with few authors, many-authored papers earn more citations.

Worst Researchers and Teaching

Career scientists at, or involved with, HSC, such as those listed in Tables 1 and 2, produce many experiments and articles but constitute a minority of researchers. Those who wrote six or more papers were only 9% of the 1,044 researchers who wrote or coauthored papers describing the results of animal experimentation. By contrast, 58% of the total number of authors coauthored only one paper and 76% coauthored only one or two papers. A total of 483 authors were involved with research experiments that garnered fewer than 13 citations.

DISCUSSION AND IMPLICATIONS FOR ANIMALS

The previous case study indicates that much research at one respected institution produces infrequently cited results. This raises the question of the value of this research and that of infrequently cited research in other settings. These results echo other studies that found that medical research papers "commonly contain methodological errors, report results selectively and draw unjustified conclusions" (Altman, 2002, p. 2765). May (1997) noted that "even if the frontiers of research are endless, each country has only a limited quantum of good research to offer. Investment beyond that point is nugatory; greater quantity is inevitably poorer quality" (p. 795). In addition to the issue of efficient use of resources, these findings raise ethical issues in regard to animal research subjects.

Many of the millions of animals used in animal experimentation annually are subjected to pain, distress, or harm (Dagg, 1999). Because housing, breeding, and feeding colonies of animals in laboratories is expensive, these animals often are recruited into experiments that are not well-thought out but merely "put the animals to productive work" to pay for their keep—"do and see" research (Weinberg, 1996, p. 21). Many research proposals have no scientific rationale other than producing cancerous lesions in a number of animals and then injecting them with various chemicals to see if the lesions are reduced in size (Dagg, 2000).

Scientists in general have a history of insisting that they must be free to carry out animal research as they see fit, indicating that "freedom of inquiry" is their inalienable right (Shapiro, 1998, p. 1). Our findings suggest that HSC could reduce its animal research effort considerably without a serious loss of knowledge. This would free up many millions of dollars for effective clinical research that, based on