The internationalisation of South African medical research, 1975–2005

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ABSTRACT

South Africa's record in the production of scientific knowledge in medicine is remarkable, but attempts have yet to be made to examine its distinctive characteristics. This is critical to the understanding of its nature, trends and the directions which it is taking today. Using the publication records extracted from the *Science Citation Index* (SCI) of the *ISI Web of Science* for a 3-decade period from 1975 to 2005, with 5-year windows, I have examined the salient characteristics of medical research in South Africa in terms of, (1) the number of publications, (2) type of publications (sole/co-authored), (3) collaboration (domestic/international), (4) affiliation sector of authors and collaborators, (5) regional origin of collaborators, (6) publication outlets and (7) citations, in comparison with 'all subjects' covered in the database concerned. This analysis shows that the contribution of medical publications to the total output of South African scholars is shrinking (25% in 1980 to 8% in 2000). Papers produced in collaboration are growing in number (increased by 17% during 1975–2005). While domestic collaboration declined by 24%, international collaboration grew from 4% of total papers in 1975 to 48% in 2005. South African medical researchers now publish more in foreign-originated journals (from 20% in 1975 to 75% in 2005) than in local journals and work mostly in universities, hospitals and research institutes; they collaborate with overseas partners from as many as 56 countries. Significantly, collaboration with Western European partners has increased 45-fold from 1975–2005. This study showed that a marked degree of internationalisation (measured in terms of international collaboration, publications in foreign journals and the number of citations) of South African medical research is taking place and that this trend is likely to continue in the future.

INTRODUCTION

Scientific publications indexed in major databases suggest that, in scientific research, South Africa is among the leading countries on the African continent.[1,2] In a 2004 classification, South Africa fell into the group of 31 countries (including the G8 and 15 EU countries) that accounted for more than 98% of the world's highly cited papers, referring to a comparator group of countries for the period of 1993–2002 [3] (South Africa was the only country in Africa to appear in this group). When all South African publications are considered together, medicine as a branch of science ranks high in terms of scientific output; a recent analysis of the publication output of South Africa during 1966–2005 revealed that medicine is the most productive discipline, with 11% of the research articles and 15% of research reviews stored in the *Science Citation Index Expanded* (SCI; 1945–present) database.[4] During 1996–2005, as another study pointed out, South Africa topped other countries in Africa in biomedicine, securing nearly one-third (28.4%) of the total African publications indexed in *PubMed*.[5] Despite this clear importance of medical research in South Africa, no attempts have been made to examine its internationalisation, although one other related study has looked at certain trends and patterns in the production of South African medical publications.[6]

Accordingly, this paper focuses on the internationalisation of South African medical science, defined as a limited number of core disciplines in medicine, namely clinical medicine, critical care medicine, nuclear medicine and tropical medicine. Internationalisation is assessed here as the (published) presence of international collaboration in South African medical science, publications of South African researchers in foreign-originated journals and the international visibility of South African medical publications, as evident in the number of citations generated in the SCI database of the *ISI Web of Science*.

I present detailed data and the methods used for this analysis in the following section, after which results delineating the characteristics of medical research in South Africa are derived from publications for the period of 1975–2005 and compared with the features of publications of South African authors and their research partners in all the fields covered in the database. The analysis is conducted in terms of, (1) the number of records, (2) the number of authors per publication, (3) the type of authorship (sole-authored/collaborative), (4) the nature of collaboration (domestic/international), (5) the publication outlets (local/foreign) and (6) the citation count.

I then explore the sectoral affiliation of the collaborators (i.e. university, research institute, hospital, government and industry) in a way that covers both South African authors and their contributing partners from overseas. For the purposes of this paper, I define the university sector as comprising universities and technikons/universities of technology, research institutes as regional and national centres where research is a major activity, the hospital sector as clinics, hospitals and medical centres, the government sector as provincial and national government departments and the industry sector as companies, firms and other business enterprises. Thirdly, I examine the regional origin of South African collaborators, grouping the countries into the regions of Africa, Asia, Australasia, Eastern Europe, Latin America, the Middle East, North America and Western Europe.

Finally, using relevant indicators of international collaboration, the types of journals in which these papers are published and the total number of citations received by South African publications, I examine the question of whether internationalisation is, in fact, taking place in medical research in

TABLE 1
South African publications in medicine and in 'all subjects', 1975–2005

Papers	1975	1980	1985	1990	1995	2000	2005	All years
Medicine								
Number of papers	378	459	523	422	266	259	202	2509
Percentage of total papers for all years (%)	15.07	18.29	20.84	16.82	10.6	10.32	8.05	100
Number of authors per paper (mean ± s.d.)	2.44 ± 1.56	2.53 ± 1.49	2.92 ± 1.66	3.16 ± 1.86	4.83 ± 17.66	5.39 ± 21.31	7.59 ± 32.39	3.65 ± 12.96
Mean fractional count (no. of papers/no. of authors) ± s.d.	0.56 ± 0.3	0.55 ± 0.31	0.47 ± 0.27	0.44 ± 0.27	0.39 ± 0.25	0.38 ± 0.26	0.36 ± 0.27	0.47 ± 0.29
Sole authored papers (%)	29.1	29.4	17.6	16.1	11.7	11.2	11.9	19.5
Co-authored papers (%)	70.9	70.6	82.4	83.9	88.3	88.8	88.1	80.5
Papers in which all authors in co-authored papers are SA (%)	68	66.9	78	74.6	76.7	56	45	68.8
Domestic collaboration in co-authored papers (%)	97.8	96.3	96.3	92.4	89.4	80.4	73.6	91.2
International collaboration in co-authored papers (%)	4.1	4.3	5.1	11	13.2	35.7	48.3	14.1
Number of collaborating countries (mean ± s.d.)	0.03 ± 0.22	0.03 ± 0.17	0.05 ± 0.24	0.11 ± 0.4	0.31 ± 2.07	0.87 ± 6.2	1.01 ± 2.41	0.24 ± 2.24
Publication in SA journals (%)	79.9	81.9	77.6	61.6	50.8	38.6	24.3	64.9
Times cited (mean ± s.d.)	8.63 ± 16.57	8.35 ± 17.19	7.47 ± 13.18	10.92 ± 26.49	13.2 ± 59.12	9.97 ± 29.54	7.3 ± 32.04	9.24 ± 28.17
All subjects								
Number of papers	1212	1828	2355	2748	2801	3361	4161	18466
Percentage of total papers for all years (%)	6.56	9.9	12.75	14.88	15.17	18.2	22.53	100
Number of authors per paper (mean ± s.d.)	2.33 ± 1.54	2.33 ± 1.69	2.64 ± 2.72	2.83 ± 1.85	3.3 ± 6.45	3.66 ± 6.99	4.56 ± 10.26	3.33 ± 6.44
Mean fractional count (no. of papers/no. of authors) ± s.d.	0.58 ± 0.3	0.6 ± 0.31	0.54 ± 0.3	0.49 ± 0.28	0.46 ± 0.27	0.43 ± 0.27	0.38 ± 0.25	0.47 ± 0.29
Sole authored papers (%)	32.2	34.4	26.5	20	17.5	14.9	11.3	19.8
Co-authored papers (%)	67.8	65.6	73.5	80	82.5	85.1	88.7	80.2
Papers in which all authors in co-authored papers are SA (%)	59	56.3	61.1	65.9	59	64.7	52.7	59.7
Domestic collaboration in co-authored papers (%)	89.2	86.8	85	85.3	74.8	68.5	60.2	74.5
International collaboration in co-authored papers (%)	13.5	14.6	16.8	17.8	28.7	40.7	53	32.1
Number of collaborating countries (mean ± s.d.)	0.1 ± 0.37	0.11 ± 0.39	0.15 ± 0.45	0.18 ± 0.52	0.36 ± 1.1	0.56 ± 1.98	0.82 ± 1.44	0.4 ± 1.23
Publication in SA journals (%)	34.9	42.3	36.8	28.7	16.3	18.5	14.3	24.5
Times cited (mean ± s.d.)	17.26 ± 83.97	14.46 ± 41.49	12.97 ± 23.9	13.17 ± 28.61	13 ± 36.58	9.74 ± 18.36	2.75 ± 8.55	10.54 ± 33.6

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South Africa, in relation to the findings of this study and within the perspective of scientific production in South Africa and in the broader international context.

DATA AND METHODS

Bibliometrics makes use of the bibliographic records of peer-reviewed publications in suitable databases to study the trends and patterns of scientific output and the impact of citations within the database concerned. The use of bibliometrics has thus proved helpful in assessing and mapping the state of science.[7] In an effort to plot the state of medical research in South Africa, this study relies on the publications records of South African authors and their partners as indexed in the *Science Citation Index Expanded* (1945–present) of the *ISI Web of Science*, for a 3-decade period from 1975 to 2005. The SCI covers a wide range of recognised and high-quality published research and citation-based scientific journals.[8] The journals in the SCI are indexed on the basis of a number of strict criteria, including citation records in the database itself. It is recognised that South African authors in the fields concerned publish many peer-reviewed papers in local and international journals that are not indexed in the SCI, but these are presently not accessible through citation indexing and can probably be taken, as a generalisation, to reflect trends similar to articles in the indexed journals.

The data for this analysis were drawn in several successive phases. In the first phase, a relevant period of data was chosen. During 1945–1965, there were no, or very few, papers by South African scholars in the ISI database, as South African publications began to appear in the database in considerable numbers only after 1971.[4] Therefore, the publications records of seven representative years (1975, 1980, 1985, 1990, 1995, 2000 and 2005) from the chosen range were used for this analysis.

In the next phase, the type of publication was considered. All publications categorised as 'articles' and 'reviews' for the selected years and which had a minimum of one South African author in the address box of the publication record were retrieved. In the end, 18 466 records of publications by South African authors from all seven selected years were extracted and entered manually into a computer program (SPSS). Of these, 2509 records (as categorised in the subject category of the ISI data) were in the fields of clinical medicine, critical care medicine, nuclear medicine and tropical medicine (i.e. they had the word 'medicine' in their title and were considered to reflect 'medical research' for the purposes of this paper).

Although the ISI database allows for some elementary classification and analysis of the records, it does not serve well for the analysis presented in this paper. The challenge, therefore, was manually to enter the attributes of each of these publications into a software program (SPSS) for statistical analysis. In this process, several new variables, including combined measures for sectors and regions, as well as partnership variables, were created from the original ISI information on record. Classification of the sectors and countries of authors, specifically

of co-authored publications, was another problem for two reasons. Firstly, the institutional addresses of authors from which the sectoral affiliation and country could be gleaned, were not available for all co-authors; this limitation was noted earlier by García-Zorita et al.[9], who found that the situation had improved in recent years. Secondly, entering all the sectoral and country attributes of all the available publication records turned out to be impractical and cumbersome, as some papers listed as many as 437 co-authors. In this analysis the sectoral and country particulars of the first five collaborators and the first five South African authors were used. As the average number of authors per publication for the period of analysis was well below five, this approach was deemed justifiable.

Collaboration of scientists happens at domestic and/or international levels. When all the research partners are from South Africa it is classified as domestic (for purposes of this paper, these authors can be either from one group, department or institution, or from more than one local institution); in international collaboration at least one author should have a primary address in another country. Mean and standard deviations were determined and appropriate statistical tests, including Pearson's correlation test, *F*-test, and one-way ANOVA, were employed for this analysis.

RESULTS

South African publications in medicine

Table 1 presents the distinctive features of South African publications in medicine compared with those within 'all subjects' (including medical sciences). Scientific publications in medicine comprised 14% (2509) of the total publications (18 466) that were produced with at least one South African author from 1975–2005. The number of South African authors of publications in medicine over the years has, however, decreased substantially, as is clear from the negative Pearson's correlation coefficient for the years and the count of publications ($r = -0.77$). In 1975, the field of medicine generated as much as 31% (378) of the total output (1212) of all South African researchers and their research partners, which, in 2005, had reduced to 5% (202 out of 4161). This decline did not occur only in percentage terms but also in absolute numbers (378 in 1975 compared with 202 in 2005) and the regression was consistent throughout the selected years of analysis: 25% in 1980, 22% in 1985, 15% in 1990, 10% in 1995 and 8% in 2000. Additionally, there was no growth in the number of publications in medicine during this period of analysis, but, rather, the average decline of these publications from the benchmark year of 1975 was -15%. These results must be viewed in contrast with the 48% gain for publications in 'all subjects' for South Africa over the same time ($r = 0.98$).

The number of scholars who take part in the production of research papers is an indication of research collaboration and partnership. The mean number of authors per paper for the entire period was higher for medicine (3.65) than for 'all subjects' (3.33), even though the number of authors per paper has increased steadily in both medicine and 'all subjects'. This trend was confirmed in one-way ANOVA tests (medicine: $F_{(6, 2502)} = 5.18$, $p < 0.01$; all subjects: $F_{(6, 18459)} = 47.05$, $p < 0.01$). The average year-on-year growth was 36% for medicine against 16% for 'all subjects'. The mean number of authors per paper in medicine had doubled to 4.83 in 1995 from the 1975 level of 2.44 and, by 2005, had tripled to 7.59. This is to be compared with only a moderate increase for publications in 'all subjects'.

The extent of collaboration was confirmed in the proportion of joint papers to sole-authored papers; South Africa generated more multi-authored papers, both in medicine and in 'all subjects', than sole-authored papers during this period. The combined efforts of more than one scholar contributed to 81% of the papers in medicine, while, for 'all subjects', the figure was 80%. From 1975 to 2005, the percentage of multi-authored papers grew by 17% and 21% in the cases of medicine and 'all subjects', respectively. In three years (1995, 2000 and 2005), the fraction of multi-authored papers in medicine grew to 89%, up from the average of 81% for the entire period of 1975–2005.

Over 90% of the co-authored papers in medicine were the product of domestic collaboration, whereas this was 75% of all

TABLE 2
Sectoral affiliations of South African researchers and their collaborators, 1975–2005

Papers	1975	1980	1985	1990	1995	2000	2005	All years
Number of South African authors per sector (mean ± s.d.)								
Medicine								
University	1.16 ± 1.08	1.02 ± 0.98	1.22 ± 1.05	1.28 ± 1.03	1.51 ± 1.36	1.76 ± 1.46	1.52 ± 1.31	1.29 ± 1.16
Hospital	0.78 ± 0.85	0.66 ± 0.8	0.64 ± 0.75	0.5 ± 0.68	0.41 ± 0.7	0.36 ± 0.73	0.29 ± 0.68	0.56 ± 0.77
Research institute	0.23 ± 0.63	0.14 ± 0.43	0.18 ± 0.47	0.26 ± 0.61	0.13 ± 0.43	0.2 ± 0.46	0.23 ± 0.63	0.2 ± 0.53
Government	0.05 ± 0.26	0.07 ± 0.3	0.04 ± 0.22	0.1 ± 0.4	0.09 ± 0.31	0.11 ± 0.52	0.13 ± 0.36	0.08 ± 0.34
Industry	0.02 ± 0.21	0 ± 0.05	0.01 ± 0.09	0.01 ± 0.08	0.02 ± 0.12	0.03 ± 0.16	0.04 ± 0.26	0.01 ± 0.14
All subjects								
University	1.16 ± 1.12	0.89 ± 0.91	1.02 ± 0.94	1.19 ± 1.06	1.26 ± 1.07	1.54 ± 1.12	1.52 ± 1.09	1.29 ± 1.08
Hospital	0.33 ± 0.68	0.23 ± 0.57	0.22 ± 0.54	0.16 ± 0.46	0.11 ± 0.44	0.09 ± 0.41	0.06 ± 0.32	0.14 ± 0.47
Research institute	0.22 ± 0.59	0.21 ± 0.48	0.24 ± 0.55	0.23 ± 0.53	0.16 ± 0.46	0.25 ± 0.63	0.23 ± 0.58	0.22 ± 0.55
Government	0.24 ± 0.68	0.15 ± 0.42	0.07 ± 0.28	0.09 ± 0.34	0.09 ± 0.31	0.04 ± 0.24	0.03 ± 0.18	0.08 ± 0.33
Industry	0.05 ± 0.3	0.04 ± 0.22	0.04 ± 0.23	0.03 ± 0.17	0.05 ± 0.24	0.03 ± 0.24	0.03 ± 0.24	0.04 ± 0.23
Number of collaborators per sector (mean ± s.d.)								
Medicine								
University	0.01 ± 0.11	0.02 ± 0.12	0.04 ± 0.23	0.08 ± 0.41	0.14 ± 0.51	0.39 ± 0.8	0.61 ± 1.08	0.13 ± 0.51
Hospital	0.01 ± 0.17	0.01 ± 0.08	0.01 ± 0.14	0.02 ± 0.2	0.03 ± 0.23	0.11 ± 0.46	0.11 ± 0.37	0.03 ± 0.24
Research institute	0 ± 0	0 ± 0.05	0.01 ± 0.14	0.02 ± 0.15	0.03 ± 0.16	0.05 ± 0.24	0.16 ± 0.52	0.03 ± 0.2
Government	0.01 ± 0.09	0 ± 0.07	0 ± 0.04	0.01 ± 0.11	0.02 ± 0.16	0.07 ± 0.34	0.11 ± 0.46	0.02 ± 0.19
Industry	0 ± 0	0 ± 0	0 ± 0.04	0 ± 0.07	0 ± 0.06	0.03 ± 0.19	0.02 ± 0.16	0.01 ± 0.08
All subjects								
University	0.07 ± 0.32	0.07 ± 0.3	0.11 ± 0.37	0.13 ± 0.48	0.25 ± 0.61	0.45 ± 0.86	0.66 ± 1.01	0.31 ± 0.73
Hospital	0.01 ± 0.18	0.01 ± 0.15	0.01 ± 0.14	0.01 ± 0.14	0.03 ± 0.23	0.05 ± 0.36	0.05 ± 0.3	0.03 ± 0.25
Research institute	0.02 ± 0.17	0.02 ± 0.14	0.02 ± 0.16	0.04 ± 0.24	0.06 ± 0.29	0.14 ± 0.5	0.25 ± 0.66	0.1 ± 0.42
Government	0.01 ± 0.12	0.02 ± 0.2	0.02 ± 0.14	0.03 ± 0.17	0.05 ± 0.27	0.01 ± 0.14	0.01 ± 0.13	0.02 ± 0.17
Industry	0 ± 0.04	0 ± 0.06	0 ± 0.06	0.01 ± 0.08	0.01 ± 0.09	0.01 ± 0.13	0.02 ± 0.15	0.01 ± 0.11

the multi-authored papers in 'all subjects'. Between 1975 and 2005, there was a decline of 24% in domestic collaboration in medicine, compared with a 29% decline in this category for 'all subjects'. The average change per every 5-year period was -4 percentage point for medicine and -5 percentage point for 'all subjects'. In multi-authored papers, the majority of the authors were South African: 69% in medicine and 60% in 'all subjects'.

In medicine, the percentage of papers (of all co-authored papers) produced as a result of international collaborations leapt from 4% in 1975 to 48% in 2005, against a rise from 14% to 53% in 'all subjects'; the average gain per every 5-year period was higher for medicine (7.37) than for 'all subjects' (6.58). International collaboration often occurred between scientists from more than one foreign country. The mean number of countries associated with medical research in South Africa was lower than that of 'all subjects' (0.24 vs 0.40). Nevertheless, year analysis showed a higher average annual (5-year span) growth for medicine than for 'all subjects' (0.16 vs 0.12), with this growth being highest in 2000. Pearson's correlation coefficients confirmed a negative growth for domestic collaboration (r = -0.68) and a positive growth (r = 0.92) for international collaboration in medicine.

South African scholars published in journals that originated both in South Africa and abroad, but initially showed a greater interest in South African journals than in foreign journals. During 1975–2005, 65% of the papers in medicine were published in South African journals, while the figure was far below this for 'all subjects' (25%). However, this trend has begun to reverse recently, as indicated in the correlation test (r = -0.87). Papers that appeared in South African journals during the study period dropped from 80% to 24% in medicine and from 35% to 14% in 'all subjects'. The annual average changes were negative for both medicine (-9.27) and for 'all subjects' (-3.43). This means the pattern changed in favour of foreign journals over locally originated ones. As for citations, South African authors and their partners in medicine lagged behind their peers in 'all subjects' in the average number of conferred citations for the aggregate period of 1975–2005.

Sectoral affiliations of authors and collaborators

Researchers were affiliated to a variety of sectors such as universities, hospitals (including clinics), research institutes (including laboratories), government departments and industry (Table 2). The mean values in respect of each of the sectors were computed for South African authors and also for their international partners in co-authored publications.

Three sectors were prominent for South African authors and these were the university, the hospital and the research institute sectors. The university sector in medicine continued to expand (except in 1980), registering an overall average growth of 0.06 points per every 5-year span. Although the mean values for 1975–2005 were the same for 'all subjects', the difference was evident between the chosen years. As expected, medicine clearly had an edge over 'all subjects' in the hospital sector. However, during the last three decades, the mean number of authors affiliated to the hospital sector declined considerably, by more than two-thirds, from 0.78 to 0.29; the average change per every 5-year period was negative. Except for a small increase of 0.02 points, there was no difference between medicine and 'all subjects' in the research institute sector; importantly, the contribution of research institutes remained unchanged over this period. In 1975, there were 0.23 South African medical researchers from research institutes and this did not alter in the following 30 years. Over the years of analysis, the sector's share in medicine declined or stagnated, while it improved by 0.01 points for 'all subjects'. The decline of the research institute sector in medicine was pronounced in 1980, 1985 and in 1995, whereas for 'all subjects' the drop was prominent in 1995 only.

A different scenario emerged for the sectors of the international collaborators of South African authors. The aggregate figures for the entire period of analysis showed that there were four prominent sectors to which collaborators were affiliated. The university sector produced the highest mean number of partners in medicine, followed by the hospital sector, the research institute sector and the government sector. However, the difference in the average values between the hospital, research institute, government and industry sectors was statistically insignificant. The order of sectors varied in the case of 'all subjects', with the university sector gaining the most, followed in order by the research institute, hospital, government and industry sectors. The proportion of medical researchers from the university sector increased steadily from 1975; from a mean value of 0.01 in 1975, to 0.61 in 2005. In the hospital sector, the change was from 0.01 to 0.11, while it was 0.00 and 0.16 in the case of the research institute sector.

Regional origins of collaborators

The international collaborators of South African medical researchers came from 56 countries around the world. A continental grouping of these countries was made as follows: Africa (excluding South Africa), Asia, Australasia, Eastern Europe, Western Europe, Latin America, Middle East, and North America (Table 3). The highest number of collaborators were from Western European and North American countries, followed by Australasia and Africa and then the Middle East and Asia. Participation of scholars from Latin America and

TABLE 3
Regional origin of collaborators of South African researchers, 1975–2005

Papers	1975	1980	1985	1990	1995	2000	2005	All years
Number of collaborators per region (mean ± s.d.)								
Medicine								
Western Europe	0.01 ± 0.136	0.02 ± 0.12	0.01 ± 0.13	0.05 ± 0.32	0.08 ± 0.35	0.22 ± 0.6	0.45 ± 0.92	0.08 ± 0.4
North America	0.01 ± 0.12	0.01 ± 0.09	0.03 ± 0.24	0.07 ± 0.37	0.06 ± 0.3	0.22 ± 0.7	0.32 ± 0.74	0.08 ± 0.39
Australasia	0 ± 0	0 ± 0.06	0 ± 0	0 ± 0.05	0.02 ± 0.15	0.09 ± 0.47	0.07 ± 0.34	0.02 ± 0.19
Africa	0.01 ± 0.1	0 ± 0	0 ± 0.09	0 ± 0.05	0.01 ± 0.12	0.06 ± 0.32	0.14 ± 0.54	0.02 ± 0.2
Middle East	0 ± 0.51	0 ± 0	0.01 ± 0.11	0.01 ± 0.1	0.01 ± 0.09	0.01 ± 0.09	0 ± 0.07	0.01 ± 0.08
Asia	0 ± 0	0 ± 0	0.01 ± 0.11	0 ± 0	0.01 ± 0.18	0.01 ± 0.09	0.09 ± 0.47	0.01 ± 0.16
Latin America	0 ± 0	0 ± 0.05	0 ± 0.04	0 ± 0.05	0.01 ± 0.12	0.02 ± 0.15	0 ± 0.07	0 ± 0.08
Eastern Europe	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.14	0 ± 0.05
All subjects								
Western Europe	0.05 ± 0.26	0.05 ± 0.29	0.06 ± 0.31	0.09 ± 0.41	0.17 ± 0.53	0.29 ± 0.72	0.42 ± 0.89	0.2 ± 0.62
North America	0.06 ± 0.34	0.06 ± 0.33	0.07 ± 0.34	0.09 ± 0.39	0.11 ± 0.43	0.21 ± 0.67	0.29 ± 0.75	0.15 ± 0.55
Australasia	0.01 ± 0.98	0.01 ± 0.08	0.01 ± 0.1	0.02 ± 0.15	0.03 ± 0.24	0.05 ± 0.3	0.07 ± 0.35	0.03 ± 0.24
Africa	0.01 ± 0.07	0.01 ± 0.08	0 ± 0.06	0 ± 0.08	0.01 ± 0.13	0.01 ± 0.09	0.01 ± 0.13	0.01 ± 0.1
Middle East	0 ± 0.06	0 ± 0.06	0.01 ± 0.11	0.01 ± 0.11	0.01 ± 0.11	0.01 ± 0.11	0.01 ± 0.12	0.01 ± 0.11
Asia	0 ± 0.04	0 ± 0.04	0.01 ± 0.09	0.01 ± 0.1	0.02 ± 0.14	0.03 ± 0.23	0.05 ± 0.32	0.02 ± 0.2
Latin America	0 ± 0	0 ± 0.02	0.01 ± 0.09	0 ± 0.05	0.01 ± 0.13	0 ± 0.06	0.02 ± 0.15	0.01 ± 0.1
Eastern Europe	0 ± 0	0 ± 0.02	0 ± 0.03	0 ± 0.03	0.02 ± 0.15	0.02 ± 0.14	0.18 ± 0.16	0.01 ± 0.11

Eastern Europe was negligible. The order of continents for 'all subjects' was similar, with the exception of Asia being higher than the rest-of-Africa and the Middle East.

In medicine, collaboration with scientists in Western Europe has increased 45-fold over the 30-year period, while it rose by only eight-fold in 'all subjects'; the highest increases were recorded in 2000 and 2005. The trend for research collaboration with North American countries (mostly the USA), is similar to that with Western Europe; in medicine, it has increased by 32-fold and in 'all subjects' by five-fold, with striking increases, observed in 2000 and 2005, as in Western Europe. Australasian countries, mostly Australia, generated the third most significant number of collaborations; although the extent of Australasian collaboration in medicine was not as significant as that of Western Europe or North America, it was important for 'all subjects'. Australasian collaboration in medicine began to grow in 2000 by nine-fold. Asian, Latin American, Middle Eastern and Eastern European alliances with South African medical researchers have been almost non-existent.

The internationalisation of South African medical research

Table 4 combines four variables of the South African medical papers produced. These are: the level of domestic and international collaboration, the number of papers published in local and foreign journals and the citations South African medical publications received for 1975–2005. As already stated, domestic collaboration, particularly since 1990 is waning and the number of records was halved in 2005 from the count in 1975. International collaboration in medicine, on the other hand grew, with an increase of publications in every chosen year. Between 1975 and 2005, international collaboration in South African medicine increased eight-fold. In 1980, it grew by 127% of the baseline 1975 figure and then expanded steadily: by 200% in 1985, by 355% in 1990, by 282% in 1995, by 745% in 2000 and by 782% in 2005. Publication in locally indexed journals declined to 49 papers in medicine in 2005, from 302 in 1975, which was just 16% of the 1975 publications. Thus, until 1985, South African scholars and their partners in medicine published in local journals rather than in foreign journals, but this trend turned around strikingly in recent times. The percentage of publications in foreign journals grew by 154% in 1985 and then by 200% in 2005, relative to the papers produced in 1975, with an average growth of 17% per 5-year period over this time. Citations of South African publications first rose from 8.63 per paper in 1975 to 13 in 1995, but then dropped to 9.97 in 2000; the overall increase in citations between 1975 and 2000 was 116%. South African publications were thus growing in terms of international collaboration, the number of papers published in international outlets of foreign journals and in international visibility as evident in the number of citations received (Figure 1).

DISCUSSION

The analysis of the scientific publications by South African authors and their collaborators indexed in the database of the *ISI Web of Science* for 1975–2005 has revealed characteristic features of South African publications in medicine and the directions in which the field of medical research has been moving. This study highlights the progressive internationalisation of South African medical research.

Although the SCI database is extensively used for collaboration studies in science it is not free from criticism, such as its bias towards the English language and towards basic research in industrialised countries[10,11] and its questionable coverage of scientific publications produced in other parts of the world.[12] Despite these limitations, the SCI database is still considered to be an indispensable tool for metastudies of science.

The total production of publications by South African scholars in the domain of medicine has declined appreciably during the period of study. The decline was especially conspicuous when the figures were compared with the publications of South Africans in 'all subjects'. Similar findings have been reported in other recent studies.[13] South African publications in clinical medicine declined during 1995–2005,[1] and the South African share of biomedical research published from the whole of Africa decreased during 1996–2005.[5] It is perplexing to find a trend of this nature here, rather than the general pattern of growth in the total publication output of South Africa. For example, it is not clear whether, in recent times, some research done in the subfields analysed (clinical medicine, critical care medicine, nuclear medicine and tropical medicine) was not published in the indexed journals adopted in the database employed in this study, or whether a substantial proportion of the research done in these fields was simply not published at all.

To assess the significance of this trend, one needs to look at the funding that research in the country receives, as medical research in South Africa appears not to be a well-supported domain of science. Scientific research in South Africa is funded by three sectors: business, higher education and science councils. According to the research and development expenditure data for 2004–2005, medical sciences received only 15% of the total expenditure of the business sector, which is the third largest

TABLE 4
Internationalisation of South African medical science, 1975–2005

Year	Number of publications	Change from 1975 (%)
Domestic collaboration		
1975	262	100
1980	315	120
1985	416	159
1990	327	125
1995	210	80
2000	185	71
2005	131	50
International collaboration		
1975	11	100
1980	14	127
1985	22	200
1990	39	355
1995	31	282
2000	82	745
2005	86	782
Local journals		
1975	302	100
1980	376	125
1985	406	134
1990	260	86
1995	135	45
2000	100	33
2005	49	16
Foreign journals		
1975	76	100
1980	83	109
1985	117	154
1990	162	213
1995	131	172
2000	159	209
2005	153	201
Citations		
1975	8.63	100
1980	8.35	97
1985	7.47	87
1990	10.92	127
1995	13.2	153
2000	9.97	116
2005	7.3	85

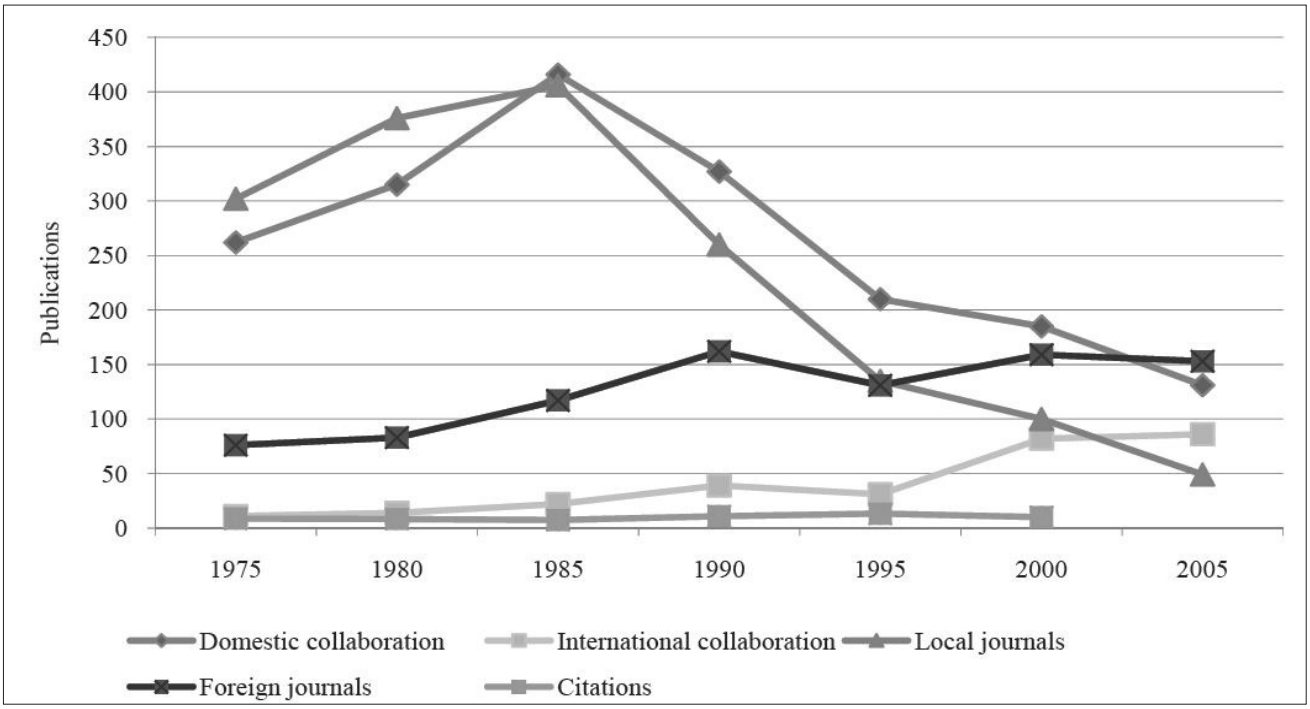

FIGURE 1
Internationalisation (collaboration, publication outlets and citations) of medical science in South Africa, 1975–2005

share after engineering (30%) and information communication technology (18%) in this sector. The higher education sector contributed the largest slice of the pie (17%) for medical sciences, while the science councils set apart only 13% for this purpose, after giving the largest share of 38% to life sciences and 18% to engineering in the same year.[14] The universities in South Africa encourage academics to undertake research and publish in scientific journals and the South African Post-secondary Education incentive system works in favour of the generation of more publications. This has not happened in medicine, however and so perhaps a more effective mechanism to motivate medical researchers, particularly those working in hospitals, is required. This mechanism should also take into account the working conditions, work-related commitments, facilities for research and career advancements for those working in hospitals. In this context, Mouton[15] argues for incentives for research collaboration that can eventually lead to more publications.

While the publication count for medical research over the years has dropped, it is interesting to note that the average number of authors per publication rose consistently from 1975 and that in this respect publications in medicine outperformed publications in 'all subjects'. It is possible that South African authors have been forced to work in larger teams because of resource constraints. Blankley et al.[16] have also observed that, compared with other disciplines, the highest percentage of collaboration in South Africa happens in clinical medicine, with 27% of co-publications, while the next closest field was the plant and animal sciences with 11%.

A majority of the papers in medicine were produced in collaboration. Domestic collaboration once generated more than 90% of the papers in medicine, but international collaboration has been growing stronger in the field of medicine than in 'all subjects'. This trend is in contrast with the experience of some other developing countries,[17] but in agreement with a developing country like China.[18] International collaboration in South Africa also often involves more than one country, which, as Persson et al.[19] phrase it, leads to an 'inflation' of international collaboration. The South African National Science Board claims that the number of internationally co-authored papers is expanding faster than nationally co-authored papers. International collaboration in general, across almost all fields of science, has actually doubled.[20] As reported by He[18], China's international collaboration with other countries has also been expanding in medical fields such as biomedical research, clinical and experimental medicine and biomedicine. Collaboration of the international kind has also been growing in the field of biometrics worldwide.[21]

The trend of South African scholars publishing in foreign journals is very evident in the data. Mouton et al.[22] reported that the proportion of articles by South Africans in foreign journals increased from over one-third to about half during 1990–2002, while 64% of the papers appeared in foreign journals in the field of medical and health sciences.

These findings do not imply that all South African journals are not internationally recognised, or that they are not suitable for article submissions. Many South African journals maintain high international standards in the quality of the papers they accept for publication, in the number of citations their papers generate and in their impact factors within medical science. Thirty-five South African journals are currently listed in the SCI database. Of these, the *South African Medical Journal* had an impact factor higher than the world median in its respective category in 2004.[23] The ISI-indexed journals do not form even 10% of the total number of scientific journals (255 in 2003–2004) recognised by the South African Department of Education.[22] On the citation front, the data show that the counts for papers in medicine have been increasing, although the rate of increase has been lower than that for 'all subjects'. Mouton[15] also points to the high citation counts of publications in foreign journals by South African authors in medicine.

South African medical researchers and their research partners mostly work at universities, hospitals and research institutes, with the majority at universities. Some researchers may have a dual affiliation with both an academic hospital and a university, but tend to use their university affiliation in publications. The government and industrial sectors have not had much impact on medical research in the country.

Although the collaborative partners of South African medical authors come from different parts of the world, most of them were from Western European and North American countries. The analysis shows poor participation of partners from African and Asian countries. According to Boshoff[24], nearly half of the collaborative papers produced in Central Africa are done so in partnership with Western European countries and about one-third of these are in partnership specifically with their past colonial rulers.

Medical research in South Africa is becoming more and more internationalised, as is shown in the analysis that employed a combined index of the measurable variables. Firstly, international participation in South African medical science is expanding, as are domestic research partnerships. Secondly, South African researchers select foreign journals, withdrawing actively from publishing in local journals. Thirdly, the increasing citation count of South African medical publications is bringing enhanced international visibility to South African medical research. Implications of this internationalisation can be envisaged in the content and directions medical research will take in the years to come. Whether this will be solely determined by the research interests of the partners who enter into partnerships with South African researchers or whether it will be shaped by the local needs of the country remains to be seen.

CONCLUSION

Despite South Africa's status as a principal producer of scientific knowledge in Africa, there is a declining trend in the production of medical knowledge in South Africa and this is of great concern. Medical research has become more collaborative than 'all subjects' in South Africa, perhaps reflecting greater resource pressures. International collaboration has expanded while domestic collaboration has fallen, perhaps also partly the result of under-resourcing. Medical researchers in the country, who initially published predominantly in local journals, now overwhelmingly support 'international' high-impact journals. Universities continue to be the centre of medical research, followed by hospitals and research institutes; however, the fact that the share of the hospital sector is diminishing is also a matter of concern for medical research in the country. Progressive disinvestment in publicly funded clinical research is clearly a primary driver of this overall situation.[25] The receipt of funds from overseas sponsors that are partly compensatory may be drivers of greatly increased international collaborative research activity; it has been estimated that foreign funding to the amount of $150 million is now spent on clinical research every year in South Africa.[26]

NOTE

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