during the first two years' observation; likewise, 82% of those existing scars that progressed had done so by the two year assessment. Probably these observations at the two year assessment are a radiological expression of fibrous contraction that has resulted from a scarring process initiated before entry into the study. The observation of new scar formation in sequential intravenous urograms is exceedingly uncommon compared with the finding of existing scarring at first investigation. Smellie *et al*, in a retrospective study of data obtained from 23 paediatric departments over 22 years, documented only 87 new scars in children aged 3 months to 9 years.[8] The lack of new scars in children less than 2 years old, coupled with the high prevalence of scarring at entry to our study, has led us to believe that the evolution of a radiologically visible scar may be so rapid in infancy that the opportunity to observe it in sequential intravenous urograms is usually missed.

The persistence of reflux in more than half of the patients treated medically for five years is at first disappointing; it was significantly more likely to happen when reflux was bilateral. Nevertheless, it did not influence renal growth or scar formation. Although recruitment to this trial has now been stopped, we intend that the patients already under study should, as far as possible, be followed up indefinitely so that the effects of reflux that persists into adulthood can be evaluated.

Our results have failed to show superiority for either form of treatment. The choice of treatment therefore remains a value judgment governed by such local factors as parental preference, the availability of surgical skill and facilities for promptly detecting breakthrough urinary infection, and willingness to comply with prolonged chemoprophylaxis. Certainly surgery reliably abolishes reflux, but whether reflux in itself is important in the long term is unknown. Clearly neither treatment is capable of completely protecting the kidneys from progression of scarring or even, on occasion, the formation of a new scar. Indeed the high prevalence of parenchymal damage already present at entry to the study serves to emphasise the need for more prompt and vigorous treatment and investigation of the first infection, which probably initiates the scarring process.[9] The more favourable renal growth pattern exhibited by children of 5 years and under implies that this is the age group most likely to benefit from such attention.

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References

1 Birmingham Reflux Study Group. Prospective trial of operative versus non-operative treatment of severe vesicoureteric reflux: two years' observation in 96 children. *Br Med J* 1983;**287**:171-4.
2 Birmingham Reflux Study Group. A prospective trial of operative versus non-operative treatment of severe vesicoureteric reflux: 2 years' observation in 96 children. In: Hodson CJ, Heptinstall RH, eds. *Contributions to nephrology: reflux nephropathy update*. Basle: Karger, 1984:169-85.
3 Edelmann CM Jr, Barnett HL, Stark H, Boichis H, Soriano JR. A standardized test of renal concentrating capacity in children. *Am J Dis Child* 1967;**114**:639-44.
4 Eklöf O, Ringertz H. Kidney size in children: a method of assessment. *Acta Radiol [Diagn] (Stockh)* 1976;**17**:617-25.
5 White RHR, Taylor CM. The nonoperative management of primary veiscoureteric reflux. In: Johnstone JH, ed. *Management of vesicoureteric reflux*. Baltimore: Williams and Wilkins, 1984:117-36.
6 Verrier-Jones K, Asscher AW, Verrier-Jones ER, *et al*. Glomerular filtration rate in schoolgirls with covert bacteriuria. *Br Med J* 1982;**285**:1307-10.
7 Uehling DT. Effect of vesicoureteral reflux on concentrating ability. *J Urol* 1971;**106**:947-50.
8 Smellie JM, Ransley PG, Normand ICS, Prescod N, Edwards D. Development of new renal scars: a collaborative study. *Br Med J* 1985;**290**:1957-60.
9 White RHR. Management of urinary tract infection. *Arch Dis Child* 1987;**62**:421-7.

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The correlates of research success

DAVID C EVERED, JOE ANDERSON, PATRICIA GRIGGS, RICHARD WAKEFORD

Abstract

A survey was carried out of the undergraduate backgrounds and research achievements of 885 (94·1%) of all 940 medically qualified professors and readers in medical faculties in the United Kingdom. A total of 217 (24·5%) of the graduates in these senior academic positions had graduated from Oxford or Cambridge and 137 (15·5%) had an intercalated BSc. The corresponding figures for a control group matched for sex and date of graduation were 118 (13·3%) for Oxford and Cambridge (academic to control odds ratio 2·11:1) and 34 (3·8%) for the BSc (odds ratio 4·58:1). Those with an intercalated BSc in the clinical specialties raised substantially more research grants from the Medical Research Council than their peers from Oxford and Cambridge or those without a BSc. The Oxford and Cambridge group raised more grants in the non-clinical specialties. Bibliometric analysis was carried out on the United Kingdom graduates within the broad specialty of medicine (n=218) matched for date of graduation. Academics with a BSc had a better publication record over 10 years (median number of original publications 72) than the Oxford and Cambridge group (median 59) and a substantially better record than those from other schools without a BSc (median 46). Citation analysis was carried out on subsets of the above sample matched for date of graduation and frequency of publication. Those with an intercalated BSc were cited more often (8·04 citations/paper) than the Oxford and Cambridge graduates (7·63) and substantially more than their peers without a BSc (4·16).

These data show very clearly that research training or experience, or both, as an undergraduate has a substantial influence on career development and correlates positively with subsequent research performance many years later.

The Ciba Foundation, London W1N 4BN
DAVID C EVERED, FRCP, FIBIOL, director
JOE ANDERSON, PHD, research officer
PATRICIA GRIGGS, BSC, research assistant

Office of the Regius Professor of Physic, The Clinical School, Addenbrooke's Hospital, Cambridge CB2 2QQ
RICHARD WAKEFORD, MA, senior research associate

Correspondence to: Dr Evered.

Introduction

The main functions of a university department in a medical faculty are research, teaching, and—in the case of clinical departments—patient care. It is generally agreed that they are interdependent and that the creation and maintenance of an environment in which all these activities can thrive is an essential prerequisite for improving medical care. It is also agreed that the health of the research enterprise in the biomedical sciences depends on the fundamental and complementary contributions of both non-medical graduates[1-4] and medically qualified researchers.[5-7] It is therefore a matter of real concern that there has been a decline in the numbers of medical graduates engaging in research and in the numbers expressing an interest in a research career.[8] This decline has been matched by a sharp reduction in Britain's world share of publications in the biomedical sciences and its share of citations—by 11% and 27%, respectively, during the seven years 1973-80.[9]

Discussions about cutbacks and other factors which may influence the quantity and quality of medical research in the United Kingdom have been limited by an almost total absence of systematic data on the impact of training methods on medical graduates' career intentions and subsequent research performance. In recent years these discussions have focused particularly on the honours BSc courses which enable medical students to intercalate a year of study,[10] usually research oriented, to obtain a science degree.[11-14] Funds for these courses have been made available by the Medical Research Council since the mid-1960s. The number of awards rose from roughly 250 a year during the late 1960s to 380 a year during 1980-5. The number was reduced to 347 in 1985-6[15] and to 313 in 1986-7, and further substantial reductions are due to take place.

The objectives of the present study were threefold: (*a*) to examine the academic backgrounds of medical graduates in senior academic positions in medical faculties in the United Kingdom; (*b*) to identify characteristics of the undergraduate education of this population which correlate (positively or negatively) with appointment to a senior academic position; and (*c*) to examine the "research performance" of this population and identify correlates in undergraduate education.

Methods

SURVEY POPULATION

The survey population consisted of all professors and readers in medical faculties in universities in the United Kingdom. Subjects were identified using the *Commonwealth Universities Yearbook 1985*.[16] All names and qualifications were cross checked with the Medical Directory for 1985[17] and, in some cases, for earlier years to trace those subjects not listed in the 1985 annual. The following items of information were recorded on medical graduates: qualifications; place (university) of graduation; date of graduation; sex; discipline (broad categories were used—for example, medicine included neurology, cardiology, etc); and university where present appointment was held. Each medical graduate was matched with a control of the same sex who had graduated in the same quinquennium—for example, 1945-9, 1950-4, 1955-9, etc. The study subjects were randomised and each was then matched with a subject drawn from the Medical Directory for 1985. Controls were drawn from every fourth page, details of the first entry on that page (or following pages) which matched the study subject being noted.

CHARACTERISTICS OF UNDERGRADUATE EDUCATION

The main characteristics of the undergraduate education for each subject in the survey and the matched control were noted. The data were first analysed after dividing the survey population into four categories: Oxford and Cambridge (Oxbridge) graduates; graduates of other United Kingdom medical schools with an intercalated BSc; graduates of other United Kingdom medical schools without an intercalated BSc; graduates of medical schools outside the United Kingdom. These categories were selected to identify those graduates with significant exposure to research during the undergraduate period. Oxford and Cambridge students, who in the past took a somewhat longer course, are provided with the opportunity to study a topic in detail—and often this incorporates a research component. Undergraduates of other schools are able to intercalate a year of study, usually research oriented, to obtain a science degree. A few subjects had a BSc acquired before or after their medical undergraduate course, but not intercalated, and these were not included in the BSc category. Two of the new schools (Nottingham and Southampton) have incorporated a period of research or study in depth in their new curricula for all students of medicine. No graduate of either of these schools had acquired the status of professor or reader by 1984-5.

Further analyses also examined possible correlations between category of undergraduate education and senior academic appointment in relation to discipline and date of graduation (the population having been divided into three roughly equal groups by date—that is, graduated before 1952, between 1952 and 1960, and after 1960).

RESEARCH PERFORMANCE

Three indicators of research performance were noted—namely, success in raising grants from the MRC, publications, and citation rate.

Success in grant raising from the MRC—The number of grants raised by each subject from the MRC during 1974-5 to 1985-6 was noted using the MRC handbooks covering this period.[18] A record was made of project grants (three year project support), programme grants (five year programme support), block grants (substantial support for autonomous institutions), group support (special support to groups for one to five years), and units (long term research in independent units). Full definitions of these awards are given in the relevant handbooks. We noted the names of grantholders, group leaders, and unit directors only.

Publications—Publication counts were obtained for each subject in the specialty of medicine (a quarter of the study population) who was known to have graduated in the United Kingdom. Medicine was selected for this initial analysis as it was the largest single discipline. Publication counts were obtained from Medline for the period 1975-85 and, in addition, a corrected count was obtained for each subject by excluding all items which were indexed as editorials, notes, letters (other than letters to *Nature*), proceedings, and reviews. For technical reasons it was not possible to exclude books and chapters, but there were very few of these. The corrected counts therefore reflected almost exclusively the numbers of original research articles published. These data were used to compute a frequency distribution of publications for the sample population. The population was then divided into three equal parts (at the 33 and 67 centile points) to give categories of low, medium, and high publishers. This approach was used, firstly, as the distribution curve was highly asymmetrical and, secondly, to minimise the influence of any errors resulting from the use of Medline, which does not distinguish between two or more authors with the same name and initials.

Citation analysis was carried out on a subset of the above group. Citation performance was carried out on a carefully stratified and matched subsample of 54 subjects—that is, 18 each from the Oxbridge, non-Oxbridge with a BSc, and non-Oxbridge without a BSc groups. Selection was initially made from within the BSc group (the smallest group numerically). By using a random numbers routine on a computer two subjects were selected from each quinquennium of graduation and publication category—that is, publication numbers in the upper, middle, and lower thirds for the whole population. These were then matched randomly from within the same subsets in the Oxbridge and non-BSc groups. Because of small numbers it was not possible to match groups in three of the 12 possible subsets—that is, medium and low publishers who graduated in the quinquennium 1950-4 and low publishers who graduated between 1965 and 1969. Thus each subset for citation analysis was matched for graduation date and publication category to eliminate any influence from these potentially confounding variables. Citation analysis was carried out on all research papers from these subjects for the years 1981-3 inclusive. Citations on publications for that period were recorded from the Science Citation Index for the years 1983-5 inclusive to cover the peak citation time for these papers.

STATISTICAL ANALYSIS

Statistical analysis was carried out by standard techniques on the statistical package for the social sciences. The tests used in each analysis are noted below.

Results

SURVEY POPULATION

There were 940 professors and readers in medical faculties in the United Kingdom in 1985 who were medical graduates. Complete information was available on 885 (94·1%) of these, the remainder not being listed in the current Medical Directory or in previous issues (and thus could not be matched with controls). Most of the missing group were overseas graduates and in preclinical specialties. It was noted that the proportion of women in the study population overall was low (3·6%) and it was not clear from these data that this proportion was increasing.

TABLE I—*Present distribution of graduates by main specialty group. (Except where stated otherwise figures in parentheses are percentages)*

Graduate group	Clinical specialties		Service specialties		Preclinical specialties		All specialties		Odds ratio (95% confidence interval)
	Academic	Control	Academic	Control	Academic	Control	Academic	Control	
Oxbridge	143 (24·7)	82 (14·2)	40 (20·1)	26 (13·1)	34 (31·8)	10 (9·3)	217 (24·5)	118 (13·3)	2·11 (1·86 to 2·35)
Non-Oxbridge with BSc	79 (13·6)	22 (3·8)	33 (16·6)	7 (3·5)	25 (23·4)	5 (4·7)	137 (15·5)	34 (3·8)	4·58 (4·15 to 5·00)
Non-Oxbridge without BSc	313 (54·1)	382 (66·0)	112 (56·3)	135 (67·8)	38 (35·5)	74 (69·2)	463 (52·3)	591 (66·8)	0·55 (0·47 to 0·63)
Overseas	44 (7·6)	93 (16·1)	14 (7·0)	31 (15·6)	10 (9·3)	18 (16·8)	68 (7·7)	142 (16·0)	0·43 (0·34 to 0·54)
Total	579	579	199	199	107	107	885	885	

TABLE II—*Project and programme grants awarded to medically qualified professors and readers by Medical Research Council over period 1974-5 to 1985-6 by graduate category and main specialty group*

Graduate group	No of subjects	No (%) of subjects with grants	Programmes	Projects	Projects/ grantholder	Projects/ subject
			Clinical specialties			
Oxbridge	141	70 (50)	15	170	2·43	1·21
BSc	81	39 (48)	10	120	3·08	1·48
No BSc	320	135 (42)	22	285	2·11	0·89
Overseas	51	26 (51)	12	52	2·00	1·02
Total	593	270 (46)	59	627	2·32	1·06
			Non-clinical specialties			
Oxbridge	82	59 (72)	15	155	2·63	1·89
BSc	64	29 (45)	3	78	2·69	1·22
No BSc	155	80 (52)	16	191	2·39	1·23
Overseas	35	23 (66)	4	75	3·26	2·14
Total	336	191 (57)	38	499	2·61	1·49

CHARACTERISTICS OF UNDERGRADUATE EDUCATION

Table I gives the details of all graduates and their controls distributed by category of undergraduate education and main specialty group. Nearly a quarter (24·5%) of all those in senior academic positions had graduated from Oxbridge as compared with only 13·3% of the matched controls. The proportion of Oxbridge graduates in senior academic positions had increased from the earlier of the three cohorts studied (graduated before 1952) through the intermediate group to the most recent graduates (after 1960) from 23% to 29%. The relative contributions of Oxford and Cambridge to the total pool of medical graduates declined over the same period and thus the academic to control odds ratio for this group increased from 1·89:1 to 3·20:1 for the most recent graduates holding senior posts. This difference was not statistically significant. Oxford had been generally more successful in this respect than Cambridge, the odds ratio for Oxford graduates being 2·62:1 and for Cambridge graduates 1·75:1.

A total of 15·5% of the study population had taken an intercalated BSc as compared with 3·8% of controls (odds ratio 4·58:1). The proportion of those with a BSc in senior academic positions increased from 6·6% in the earliest cohort to 20·0% among those who had graduated most recently. There was also a pronounced increase of those with a BSc among the controls—that is, from 0·7% to 7·5%—reflecting the greater opportunities to take an intercalated BSc during the 1960s and early 1970s.

It is clear from these data that graduates from Oxford and Cambridge, together with those from other universities who had taken an intercalated BSc, had increasingly dominated appointments to senior academic positions, accounting for 49·1% among those most recently graduated. The proportion of graduates from outside the United Kingdom occupying senior positions had remained relatively constant (6·4-8·6%), as had the proportion in the matched controls (14·6-17·0%). Graduates from other United Kingdom medical schools without an intercalated BSc accounted for only 44·5% of appointments among the most recent graduates.

There were substantial differences among the specialties with respect to the frequency with which those in a senior academic position had graduated from Oxford or Cambridge or taken an intercalated BSc. There was a positive correlation between the frequency with which these two variables were noted in the clinical specialties ($r=0·92$, $p<0·05$; Spearman rank correlation). This analysis was carried out on the larger clinical specialties—that is, those with 25 or more subjects. An intercalated BSc was a particular characteristic of those with senior academic positions in biochemistry (32%), anatomy (25%), pharmacology (22%), physiology (21%), microbiology (20%), and medicine (18%) but was an infrequent characteristic in community medicine and general practice (9%), surgery (7%), and obstetrics and gynaecology (6%). Similarly, high proportions of Oxford and Cambridge graduates were found in physiology (39%), psychiatry (34%), biochemistry (32%), and medicine (32%) and relatively few in community medicine and general practice (16%), anatomy (15%), surgery (15%), and obstetrics and gynaecology (6%).

RESEARCH PERFORMANCE

Success in raising research funds from MRC

The number of grants raised from the MRC by each subject in the study over the period 1974-5 to 1985-6 was noted with particular reference to project and programme grants (see table II).

In the clinical specialties success in raising grants was similar among the Oxbridge and BSc graduates, roughly half of each group being successful in raising at least one grant from the MRC during the period. Those with a BSc were more successful, however, in terms of the number of grants raised—that is, 3·08 project grants per grantholder compared with 2·43 in the Oxbridge group. Both groups were more successful than other United Kingdom graduates without a BSc; only 42% of these graduates raised at least one grant over the period, and the average number of grants raised was somewhat lower (2·11 grants per grantholder). The difference in the proportions of those with and without a BSc who were successful in raising grants was not significant. If, however, the number of grants raised is taken into account then the difference between the non-Oxbridge British graduates with and without an intercalated BSc was significant at the 1% level ($t=2·77$; $p<0·01$). A somewhat greater difference was noted in the raising of programme grants, the figures being Oxbridge 15 grants (0·11 per subject), BSc group 10 grants (0·12 per subject), and non-BSc group 22 grants (0·07 per subject).

In the non-clinical specialties the graduate category with the greatest success in raising grants was the Oxbridge group. A significantly greater proportion of this group successfully raised grants than either the BSc group ($\chi^2=10·7$; $p<0·01$) or the non-BSc group ($\chi^2=9·1$; $p<0·01$).

Publications

Publication counts were obtained for each subject in the specialty of medicine who was known to have graduated in the United Kingdom. This subset was composed as follows: Oxbridge graduates, 76; non-Oxbridge with BSc, 43; non-Oxbridge without BSc, 99; overseas, 14; and not known, 3. With the exclusion of the last two groups the analysis was therefore carried out on 218 subjects.

There was a very close correlation between the total number of publications (raw counts) and the number of original research articles published (adjusted counts) by each subject. There was a high correlation between these values (r=0·99; n=217). This highly significant linear relation applied across all cohorts and over all graduation dates.

There were significant differences among the numbers of publications produced by the different graduate groups (table III). The BSc category had substantially more high publishers and fewer low publishers than the other two categories. The cross tabulation between graduate group and publishing categories, however, may have been confounded by graduation date, as the BSc group contained a higher proportion of more recent graduates than the other degree cohorts and a trend towards increasing publication counts was noted among the more recently graduated cohorts. The median numbers of publications during the period 1975-85 for all categories of graduates by quinquennium of graduation were: 1945-9, 32; 1950-4, 40; 1955-9, 60; 1960-4, 61; 1965-9, 70; and 1970-4, 53. The last group had, of course, only just graduated at the start of the period of the Medline search.

To compensate for this potentially confounding variable graduation date was controlled for by matching groups. An equal number of subjects was drawn at random from each graduate group and matched by quinquennium of graduation. Table IV gives the publication data for these matched groups and shows clearly that those with a BSc had higher publication rates than Oxbridge graduates, who in turn had a higher rate than the non-BSc group, though this difference was not significant.

Further analysis was carried out comparing groups with and without a BSc directly. Of these groups, 66% and 37% respectively had publication counts greater than the median. The difference between the two groups was significant (χ^2=5·7; p<0·01). Hence non-Oxbridge graduates selected for an intercalated BSc had published greater numbers of research articles in refereed journals than their peers without such degrees who had also reached senior academic positions.

TABLE III—*Numbers of original research papers published by professors and readers of medicine between 1975 and 1985*

	Publication counts			No (%) of subjects in each category		
Graduate group	Mean	Median	Range	High	Medium	Low
BSc	93·1	75	10-311	24 (55·8)	10 (23·3)	9 (20·9)
Oxbridge	63·4	51	0-620*	24 (31·6)	26 (34·2)	26 (34·2)
Non-BSc	54·9	41	0-214	26 (26·3)	34 (34·3)	39 (39·4)
All groups	62·8	48	0-620	74 (33·9)	70 (32·1)	74 (33·9)

χ^2=12·22; df=4; p<0·02.
*This figure of 620 publications is twice that of the next most frequent publisher with 311 publications.

TABLE IV—*Numbers of original research papers published by professors and readers of medicine matched by date of graduation*

	Publication counts		No (%) of subjects in each category		
Graduate groups	Mean	Median	High	Medium	Low
BSc	85·5	72	17 (48·6)	9 (25·7)	9 (25·7)
Oxbridge	64·2	59	10 (28·6)	11 (31·4)	14 (40·0)
Non-BSc	53·3	46	9 (25·7)	11 (31·4)	15 (42·9)
All groups	67·7	58	36 (34·3)	31 (29·5)	38 (36·2)

χ^2=5·88; df=4; p>0·05.

TABLE V—*Citation figures 1983-5 for publications 1981-3. Professors and readers of medicine matched by date of graduation and publishing category*

Graduate group	Total papers	Total citations	Citations/paper	No (%) of papers cited at least once	No (%) of papers cited 20 or more times
Oxbridge	347	2649	7·63	290 (83·6)	29 (8·4)
BSc	346	2781	8·04	294 (85·0)	35 (10·1)
No BSc	293	1218	4·16	221 (75·4)	11 (3·8)

Citation analysis

Table V gives the citation figures for the matched subset. Each graduate group was separated into high and low cited authors by the median citation rate for the whole subset—that is, 5·15 citations per publication. The χ^2 value for these categorical data just failed to achieve significance (p=0·056). Direct comparison of the BSc and non-BSc groups using the median for these two groups (4·82 citations per publication) did, however, show a statistically significant difference (χ^2=4·00; p<0·05). After random sampling we noted a difference between the total number of papers published by the BSc group compared with the non-BSc group and found a significant positive correlation between total papers published and citation rate (r=0·429; p<0·01). The statistical analysis was therefore repeated after increasing the citation rates of the non-BSc group by the factor (53×0·09)/18, where 53 is the difference in the number of papers between the BSc and non-BSc groups, 18 is the number of subjects in the group, and 0·09 is the regression coefficient for the relation between publication counts and citations. A significant difference between the two groups was still obtained after applying this correction (p<0·05).

Discussion

Biomedical research and the universities in the United Kingdom are under considerable financial pressure. It is essential that we should know more about the impact of training methods on medical graduates' career intentions and research performance if we are to use scarce resources to best effect.[19] This study provides the first complete description of the undergraduate background of all medical graduates in senior academic positions in the United Kingdom. The findings show very clearly the established and increasing importance of the intercalated BSc year and of the Oxford and Cambridge systems. These sources accounted for 29%

of senior academics who graduated before 1952, 42% of those who graduated between 1952 and 1960, and 50% of those who graduated after 1960. These figures compare with 14%, 18·5%, and 19% of a matched sample drawn from the general medical population for the same periods; thus the contributions of the intercalated BSc year and Oxbridge increased in both absolute and relative terms.

There were several important differences among disciplines; nevertheless, there was a greater proportion of subjects who had taken an intercalated BSc among the academics in all disciplines than in the matched controls, and an Oxbridge education was found more frequently among the academics in all disciplines other than anaesthetics and obstetrics and gynaecology. These frequencies, however, varied widely. An intercalated BSc had been taken only 1·7 (odds ratio 1·71:1) times as frequently by those in obstetrics and gynaecology by comparison with the controls, but 8·5 (odds ratio 11·95:1) times as frequently in biochemistry. A similar range was noted for an Oxbridge undergraduate education, with figures ranging from 0·5 times (odds ratio 0·44:1) in obstetrics and gynaecology to 2·9 times (odds ratio 4·08:1) in physiology. In general those who had taken an intercalated BSc were more likely to pursue a career in a preclinical subject or medicine and those with an Oxbridge education more likely to take up an academic career in a preclinical subject, medicine, mental health, or child health.

These data are of considerable interest, and it seems very probable that either an intercalated BSc year or an Oxbridge undergraduate education makes important contributions to the choice of a career in academic medicine, thus confirming our earlier observations.[11]

Arguably, however, the processes in selection for an Oxford or Cambridge education and for an intercalated year do no more than identify the most able and the most highly motivated. Intuitively we accept that these factors are likely to play a part in directing pupils towards Oxbridge or an intercalated BSc, and this point was made clearly by Wyllie and Currie for those taking an intercalated BSc in pathology in Edinburgh.[14] We therefore extended our study to examine the "research performance" of senior academics in the United Kingdom, making the assumption that all those who had achieved high academic status, whatever their undergraduate background, were (or had been) highly motivated and also among the intellectually most able of their peer group.

The study of research performance was carried out in three stages. We initially examined success in raising grants from the MRC. We are aware that the MRC is far from being the only source of research funds. An earlier study showed that in 1980, 34% of grants for biomedical research in the universities were derived from the MRC, 12% from other research councils, 21% from the main charities, and the remaining 33% from a wide range of other sources—for example, health service funds, pharmaceutical and equipment companies, international bodies, and local charities.[4] These figures have probably changed over the past five years, particularly with the relative and absolute increase in the contributions by the charities, but we know of no more recent data. The MRC remains, however, the largest single source of funds for biomedical research in United Kingdom universities and it would not be possible to collect reliable and representative data from the many other sources. Furthermore, there has been no appreciable change in the methods used by the MRC for evaluating grant applications over this period. These data show that an Oxbridge education (in the case of non-clinical specialties) or an intercalated BSc year (clinical specialties) is positively correlated with success in raising grants. The data also suggest that these groups are most active in research, though we acknowledge that the value of these data is limited by the fact that no more than one third of the grants awarded are derived from the MRC and it is possible that there may be some systematic bias in the selection processes which favours applicants with an Oxbridge background or an intercalated BSc ("halo effect").

The next stage of the study entailed examining publication performance. It is clear that all who engage in research have as a short term aim the publication of their results. The publication performance of an individual scientist therefore reflects research activity, effort, and achievement. The analysis of publications was carried out on all professors and readers in medicine, this being the single largest discipline, comprising a quarter of the study population. The reason for selecting a single discipline was to eliminate one potentially confounding variable—namely, the systematic differences in publication patterns and citation practices which are known to exist among disciplines. At least one grant had been successfully raised from the MRC by 50-51% of all three graduate groups in the specialty of medicine during the 12 year study period. The average number of grants raised by each subject in the BSc group was, however, significantly greater than that in the other two groups (3·64 *v* 2·63). It is clear from both the raw data and after matching subjects for date of graduation that subjects in the BSc group published more papers than the Oxbridge group, which in turn published more than the non-BSc group, and that the differences between the BSc and non-BSc groups were statistically significant. It would appear that research training and experience in the undergraduate period is reflected in greater research activity many years later when all these graduates have achieved equally senior academic positions.

Numbers of publications can reasonably be looked on as an index of productivity but should not be used as a direct measure of quality or impact on the scientific community. A positive correlation between "quantity" and "quality" has been claimed by some workers[20] but in many instances this correlation is small or zero and, as Martin and Irvine have pointed out,[21] publication numbers should be regarded only as a "partial indicator" of scientific progress. Citation analysis, a direct measure of impact, was therefore carried out on a matched subset from the group within medicine. This analysis disclosed that the citation rate of those in the BSc group was greater than that of the Oxbridge group, which in turn was greater than that of the non-BSc group. The difference between the BSc and non-BSc groups (who were drawn from the same undergraduate population) was statistically significant, even after correcting for all major confounding variables.

It is clear from this study that research training or experience, or both, as an undergraduate has a positive influence on career intentions and subsequent research performance. It is, in fact, remarkable that these influences are so powerful when the youngest subjects in the study had graduated more than 10 years previously and the median time between date of graduation and 1985 was no less than 29 years. We acknowledge that these data are not absolutely conclusive (but this is equally true of most studies in clinical research and the biosciences). It is possible that Oxbridge and BSc graduates may receive career preferment for reasons unrelated to merit. Equally those with undergraduate research training may have their first grant applications looked on more favourably, though it is unlikely that this factor would operate for second or subsequent applications in the absence of satisfactory performance. It may also be argued that these graduates, for all these reasons, have opportunities to work in the most favourable environments and that this gives them career and research advantages.

Probably all these things are partially true. It is, however, inherently very unlikely that they are entirely unrelated to ability and performance. It is striking that, with as satisfactory control groups as can be obtained (that is, senior academics who have achieved identical status without career advantages derived from their undergraduate training), there was such a high level of concordance among the various indicators which were observed. These observations, together with those in earlier reports,[9 10 12] provide strong evidence that the intercalated BSc is of real importance in developing a cadre of trained research workers for the future. The assertion by the National Audit Office that "the awards made by the Council under this scheme have become of . . . a general educational (rather than research) nature" (quoted by the First Secretary of the MRC in a letter to the deans of medical faculties in the United Kingdom, November 1985) appears to have little foundation. A substantial reduction in the number of undergraduates having the opportunity to intercalate a year would certainly have an impact on the number of highly trained clinical researchers in the latter years of this century and beyond.

We emphasise that this study was purely designed to examine factors in undergraduate education which might determine a research career and have an influence on research performance. We are fully aware that research is only one essential activity of university departments in medical faculties, the others being teaching and establishing the highest standards of clinical and laboratory practice. It is not possible from these observations to comment on what influence, if any, an intercalated BSc or an Oxbridge education may have on teaching abilities or on standards of practice.

An important general conclusion may also be drawn from these studies. It is clear that the case for continued public support of biomedical research (whether by government agencies, charitable bodies, or industry) must in future be based on hard evidence and not on anecdote. This study shows very clearly that well conducted systematic inquiries can yield data which are of value for formulating policy and determining funding strategies.

References

1 Comroe JH, Dripps RD. Scientific basis for the support of biomedical science. *Science* 1976;**192**:105-11.
2 Perutz MF. Fundamental research in molecular biology: its relevance to medicine. In: Wolstenholme G, O'Connor M, eds. *Research and medical practice: their interaction*. Amsterdam: Excerpta Medica, 1976:115-35. (Ciba Foundation symposium No 44.)
3 Geschwind N. Clinician-scientists. *Science* 1984;**224**:239.
4 Sadler J, Porter R, Evered D. Careers of non-medical graduates in British medical research. *Nature* 1981;**293**:423-6.
5 Oliver MF. The shrinking base of clinical science: where are tomorrow's researchers? *Eur J Clin Invest* 1977;**7**:1-2.
6 Wyngaarden JB. The clinical investigator as an endangered species. *N Engl J Med* 1979;**301**: 1254-9.
7 Booth CC. Clinical science in the 1980s. *Lancet* 1980;ii:904-7.
8 Thier SO, Challoner DR, Cockerham J, *et al*. Proposals addressing the decline in the training of physician investigators: report of the ad hoc committee of the AAMC. *Clinical Research* 1980;**28**:85-93.
9 Martin B, Irvine J, Turner R. The writing on the wall for British science. *New Scientist* 1984;**1429**:25-9.
10 Cohen Lord, Williams E, McLachlan G, eds. *Report of the General Medical Council survey: basic medical education in the British Isles*. London: Nuffield Provincial Hospitals Trust, 1977:45-52.
11 Wakeford R, Lyon J, Evered D, Saunders N. Where do medically qualified researchers come from? *Lancet* 1985;ii:262-5.
12 Eaton DG, Thong YH. The Bachelor of Medical Science research degree as a start for clinician-scientists. *Med Educ* 1985;**19**:445-51.
13 Smith R. A senseless sacrifice: the fate of intercalated degrees. *Br Med J* 1986;**293**:1619-20.
14 Wyllie AH, Currie AR. The Edinburgh intercalated honours BSc in pathology: evaluation of selection methods, undergraduate performance, and postgraduate career. *Br Med J* 1986;**293**: 1646-8.
15 Medical Research Council. *Handbook 1986*. London: Medical Research Council, 1986:273.
16 Association of Commonwealth Universities. *Commonwealth Universities yearbook 1985*. Vol 1. London: The Association of Commonwealth Universities, 1985.
17 *The Medical Directory 1985*. Harlow, Essex: Churchill Livingstone, 1985.
18 Medical Research Council. *Handbooks 1974-5 to 1985-6*. London: Medical Research Council, 1974-86.
19 Anderson J, Evered DC. Why do research on research? *Lancet* 1986;ii:799-802.
20 Price D deS. *Little science: big science*. New York: Columbia University Press, 1963:41.
21 Martin BR, Irvine J. Assessing basic research: some partial indicators of scientific progress in radio astronomy. *Research Policy* 1983;**12**:61-90.

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SHORT REPORTS

Impaired intravascular lipolysis with changes in concentrations of high density lipoprotein subclasses in young smokers

Concentrations of high density lipoprotein (HDL) cholesterol, a negative risk factor for coronary heart disease, are lowered and those of triglyceride raised in young smokers independently of age, sex, obesity, alcohol consumption, and use of oral contraceptives.[1] After a standard fatty meal concentrations of triglyceride increase more and remain raised for longer in smokers than in non-smokers.[2] Furthermore, a postprandial rise in the concentration of HDL_2 cholesterol and the ratio of HDL_2 to HDL_3 cholesterol is observed in non-smokers but not in smokers.[2]

To ascertain whether these differences can be explained by differences in rates of intravascular lipolysis, we used the intravenous fat tolerance test with Intralipid[3] in carefully matched groups of smokers and non-smokers.

Subjects, methods, and results

Twenty male medical students volunteered, 10 of whom regularly smoked (mean consumption 15 cigarettes/day). The two groups were matched for age (mean 21, range 19-23 years) and body mass index (smokers mean (SD) 22·7 (2·0), non-smokers mean (SD) 21·6 (1·7), p=0·1). Levels of alcohol consumption and physical exercise were similar in all subjects.

The fractional removal rate (K2) of a bolus of injected Intralipid (10%, 1 ml/kg) was determined after an overnight fast. Cholesterol and triglyceride concentrations were measured enzymatically on a centrifugal analyser with Boehringer reagent kits. HDL cholesterol and HDL_3 cholesterol were measured after isolation by selective precipitation with dextran sulphate 50 000-$MgCl_2$; HDL_2 cholesterol was calculated by difference. Tests for the significance of differences between group means with pooled estimates of variance were performed on an Apricot Xi computer with the Microstat statistical package.

The fractional removal rate of Intralipid (K2), which correlates closely with plasma postheparin lipoprotein lipase activity, was significantly lower in smokers (p=0·032) (table). The concentration of HDL_2 cholesterol and the ratio of HDL_2 to HDL_3 cholesterol were also significantly lower in smokers (p=0·043, p=0·02 respectively), but the concentration of HDL_3 cholesterol was significantly higher (p=0·003). The concentrations of plasma triglyceride and total cholesterol were higher and that of total HDL cholesterol lower in smokers than in non-smokers, but these differences were not significant.

Mean fasting plasma lipid concentrations mmol/l (SD) and Intralipid elimination constant %/min (SD) in smokers and non-smokers

	Non-smokers (n=10)	Smokers (n=10)	p Value
Cholesterol	4·31 (0·55)	4·62 (0·92)	0·189
Triglyceride	0·82 (0·23)	1·04 (0·43)	0·088
HDL cholesterol	1·34 (0·27)	1·32 (0·22)	0·444
HDL_2 cholesterol	0·45 (0·24)	0·29 (0·15)	0·043*
HDL_3 cholesterol	0·88 (0·11)	1·03 (0·11)	0·003*
HDL_2:HDL_3 cholesterol	0·52 (0·33)	0·27 (0·13)	0·020*
K2-Nephelometric	7·30 (2·12)	5·71 (1·41)	0·032*

*Significantly different.

Comment

The action of endothelial lipoprotein lipase on triglyceride rich lipoproteins reduces the core volume of these particles and generates surface remnants containing unesterified cholesterol, phospholipid, and apoprotein, which join the HDL_3 pool. These surface remnants are thought to constitute the major source of HDL precursors and lipoprotein lipase is thought to be a major determinant of the plasma concentration of HDL. Esterification of the acquired free cholesterol in HDL_3 particles by lecithin cholesterol acyltransferase results in the accumulation of cholesterol ester in the core of the particles and the production of larger, less dense HDL_2 particles.

A transfer protein mediates the exchange of cholesterol ester in high density lipoproteins with triglyceride in lipoproteins of a lower density. The magnitude of postprandial lipaemia determines the extent of this exchange and the resultant triglyceride content of HDL_2 particles.[4] Furthermore, the triglyceride content of HDL_2 particles has been shown to determine which of the phospholipase or triglyceride lipase activities of hepatic lipase act on them: triglyceride rich HDL_2 particles are converted to HDL_3 particles by the removal of triglyceride from the core of the particles, whereas phospholipid is removed from the surface of triglyceride poor HDL_2 particles without any change in size or density.[4]

We have shown reduced intravascular lipolysis in smokers. We suggest that the consequent increase in postprandial lipaemia in smokers will result in a greater proportion of HDL_2 particles being converted to HDL_3 particles by hepatic lipase. This would explain the lowering of the concentration of HDL_2 cholesterol, the increase in the concentration of HDL_3 cholesterol, and the fall in the ratio of HDL_2 to HDL_3 cholesterol found in our smokers. The concentration of HDL_2 cholesterol correlates negatively with the severity of angiographically defined atheroma.[5] The changes in high density lipoproteins that we report in young smokers and the increased exposure of the vascular endothelium to potentially atherogenic lipoproteins as a consequence of impaired clearance of triglyceride rich lipoproteins may