Training a New Generation of Biostatisticians: A Successful Consortium Model

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In response to the worldwide shortage of biostatisticians, Australia has established a national consortium of eight universities to develop and deliver a Masters program in biostatistics. This article describes our successful innovative multi-institutional training model, which may be of value to other countries. We first present the issues confronting the future of biostatistics in Australia, then relate our experience in establishing a new national consortium-based Masters program, and finally explore the extent to which our initiatives have addressed the current challenges of biostatistics workforce shortages.

1. Introduction

There is a widely recognized shortage of graduates in biostatistics relative to what appears to be a continually increasing demand for expertise in this area. DeMets et al (2006) review this issue in relation to the U.S. , pointing out that the demand for biostatisticians has grown dramatically in the past 20 years. Statistical expertise has become central to many areas of research and health service activity, including not only more traditional areas such as clinical trials and epidemiological studies, but also the rapidly emerging fields of statistical genetics, bioinformatics and computational biology.

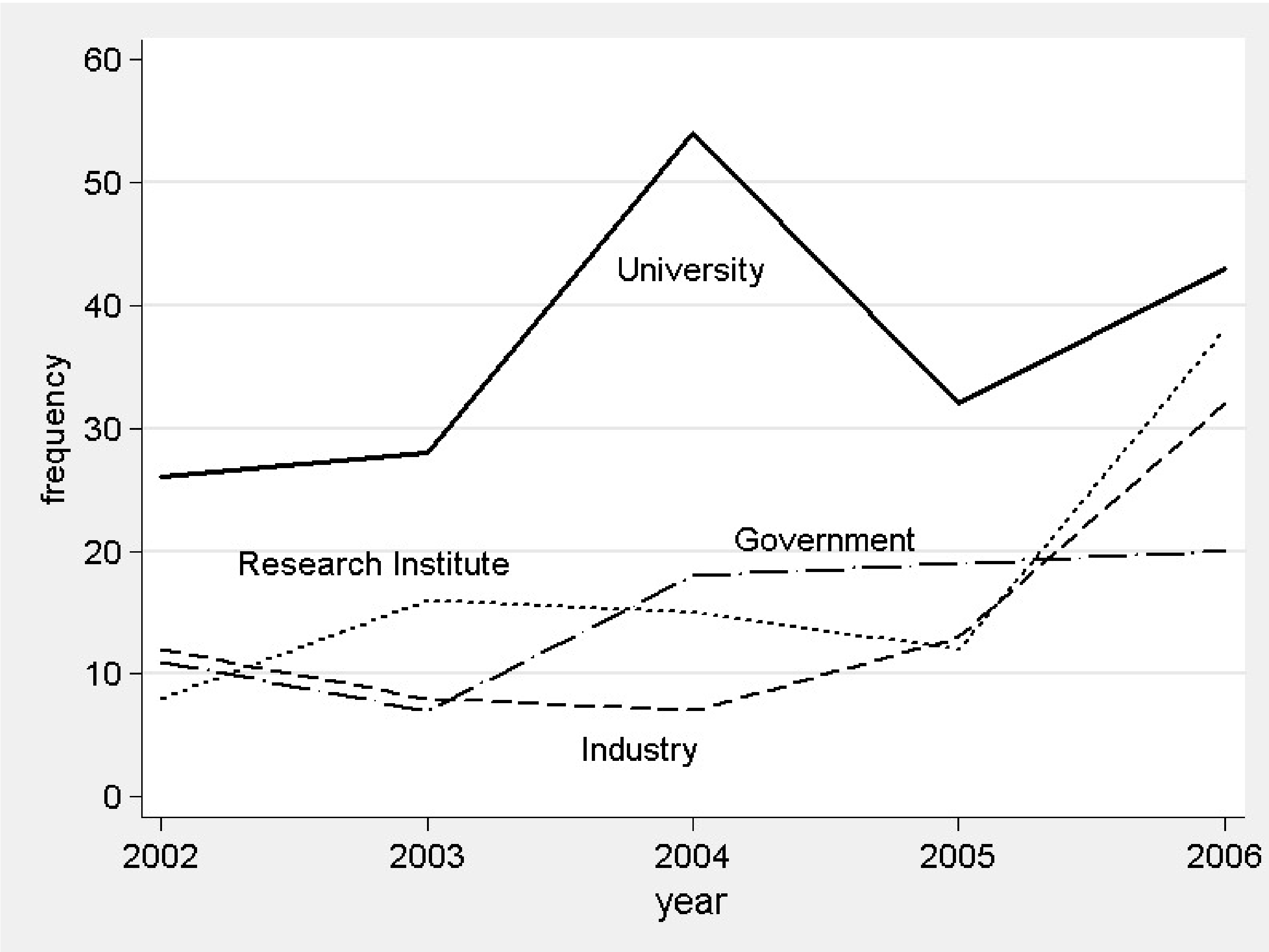
DeMets et al. (2006) describe the U.S. context where a substantial investment in training by the National Institutes of Health (NIH) in the late 1960s and early 1970s helped to create a cadre of academic biostatisticians. This group has provided leadership to the field but major difficulties are now evident in identifying a new generation of adequate size and strength to meet burgeoning demands. These authors commented that the "situation world-wide is probably similar to that experienced within the U.S." but did not further address the issue in other settings.

2. The Market for Biostatisticians in Australia

Biostatistics has struggled to establish itself as an independent academic discipline in the Australian context, and the term itself has only recently been widely adopted, in place of the traditional British term "medical statistics". However, there has been a clearly increasing recognition of the contribution of biostatistical expertise to an ever-expanding range of areas in medical, genetic, public health and health services research.

What firm empirical evidence do we have of increasing demand for biostatisticians in Australia? There are limited data available but useful information can be gleaned from the records of a web-based repository for employment advertisements (www.statsci.org), which lists all jobs advertised on the email list "ANZSTAT" (www.maths.uq.edu.au/research/research_centres/anzstat/), most Australian newspapers and other commercial services, and is thus an almost complete archive of all statistics jobs advertised in Australia. Figure 1 shows the source of the 419 biostatistics positions advertised in Australia from 2002 to 2006. It shows that demand has increased across all sectors in the past five years. The number of positions advertised increased by 17 per year on average during that period, while the number requiring a PhD increased by just over 2 per year from an average of 13 in 2002-2003.

Figure 1. Frequency plot of source of biostatistics positions in Australia by year



The existence of a general shortage of graduates in the mathematical sciences attracted public discussion in 2007 with the publication of a high-level national review of the mathematical sciences (Australian Academy of Sciences, 2006). This review cited "clear evidence that the current supply of trained mathematicians and statisticians is inadequate and decreasing", adding that "the situation for statisticians is already dire, with major sectors such as medical research and development now unable to recruit appropriately trained statisticians within Australia."

In a similar vein, a national review by the Statistical Society of Australia (2005) found a "recurring concern expressed [about] the dwindling number of staff and declining or relatively static numbers of undergraduate students within traditional (mathematical) statistics programmes in universities." Furthermore, the review reported that the number of research higher degree (PhD) completions in statistics in Australia (population approximately 20 million) had hovered at little over 20 for almost ten years up to 2003. It appears that many students with the potential for careers in biostatistics are attracted away at early stages of their training into fields such as information technology and business.

Although neither of these reviews focused specifically on biostatistics, the challenges in this area have been recognized at least as far back as the late 1990s, when a national review of the federally funded Public Health Education and Research Program (PHERP) recommended that "a working party be established to examine ways by which Australia's supply of biostatisticians can be enhanced. This working party should include representatives from both within and outside the public health workforce. Depending on the outcomes of this process, special PHERP innovation funds should be considered as a means to support increasing the pool of biostatisticians in Australia" (Nolan, Bryson & Lashof, 1999).

These reviews have encompassed a broad range of levels of professional competence but it seems clear that a particularly glaring problem exists at the level of doctoral and postdoctoral training. Completion of Honours degrees (the traditional British-style four-year degree in which the fourth year consists largely of a research project) in mathematics and statistics at Australian universities grew rapidly in the 1960s but has been stable since 1970 at about 150 per year, with a notable exception in the first half of the 1990s when there were more than 200 graduates annually (Australian Academy of Sciences, 2006). PhD graduations in mathematics and statistics have increased from about 40 per year between the mid-1960s and mid-1990s to the current level of about 80 per year. This has been offset by the number of research Masters degree completions in mathematics and statistics, which has declined from a peak of 40 per year in the late 1970s to about 20 per year now. In summary, there are fewer than 100 people graduating each year from Australian universities with research higher degrees in mathematics or statistics (Australian Academy of Sciences, 2006).

DeMets et al. (2006) report data on increases in median salary levels for a range of academic biostatistics positions in the U.S. over the 10-year period 1995-2005. These indicate a rate of increase somewhat greater than the rate of inflation, with an average increase of 26% over the 5-year period from 2000 to 2005. Similar data are difficult to find for the Australian market, although data from four major universities show that salaries for lecturers increased by an average of 24% over the 5-year period from 2002 to 2007 while the Consumer Price Index increased by 14.4% (Australian Bureau of Statistics, 2007). The number of biostatisticians employed in the pharmaceutical industry has expanded rapidly in the past decade in Australia but is still small; a recent commercial review of remuneration showed an average 9.4% increase in the two years from 2005 to 2007, similar to the rate of increase for academics.

3. The Biostatistics Collaboration of Australia

Given the context of increasing market demand for biostatistics, the university sector in Australia was clearly not responding effectively in the late 1990s. Over the previous decade a number of academic Departments of Statistics had been closed, or merged with Mathematics Departments (and this in the context, previously discussed, of shrinking support for all areas of the mathematical sciences). Very small numbers of graduates were being produced at all levels of the system. Biostatistics groups were small and invariably existed as informal organizational units within Departments of Epidemiology and Schools of Public Health.

However, following the 1999 PHERP review, a group of biostatisticians recognized an opportunity for government seed funding to be provided for a new training program and conceived a consortium model through which this could be established. As a result, the Australian government agreed to provide $AUD1.2 million over five years from 2001 for the establishment of the Biostatistics Collaboration of Australia (BCA). The Collaboration initially comprised a consortium of seven universities (recently expanded to eight), which agreed to offer a new Masters program in Biostatistics in partnership with each other. Between one and three academic biostatisticians from each of the universities have been closely involved, first in developing the curriculum and subsequently in delivering the program.

Teaching is done by distance delivery, with course materials sent to students in printed form, and an online learning management system used to generate class interaction and to manage assessment. Students must enrol at one of the consortium universities, which becomes their "home" university. All units of instruction are accredited by all consortium universities and each unit is delivered by one and only one of these universities in any semester. Students enrolled in the same unit at different universities receive identical course materials and instruction. A central BCA coordinating office functions as a liaison and communication centre for students, coordinators and administrators at all BCA participating universities. Details of how aspects of distance delivery are handled within the program have been published by Heller et al. (2008).

The BCA program has been re-funded by the Australian government for another five years to 2010, at a level sufficient to support the transaction costs incurred by the multi-university consortium model. Most of the funding to support the courses comes from tuition fees paid by the students. These fees are redistributed within the consortium according to an agreed model that proportionately rewards those university partners that carry larger teaching loads, with a weighting that allows cross-subsidization of the more advanced (often elective) units of the program. A small financial contribution is made by pharmaceutical industry partners, in the form of competitive scholarships that cover fees. Although the program is now operating on a reasonably self-supporting basis, the injection of government support was crucial in enabling its establishment and is still required to ensure a stable administrative base. In particular, financial support for the development of a completely new curriculum, designed for distance education, was essential.

4. The BCA Program

Students may take courses in the BCA program to three levels: the Master of Biostatistics degree comprises 12 units of study (subjects); embedded within it are the Postgraduate Diploma (8 units) and the Postgraduate Certificate (4 units). Students enrolled in the Masters or Postgraduate Diploma may exit the program with a lesser degree, provided they have successfully completed the requirements. The required units of study for each course are displayed in Table 1. Details of the content of each unit and the textbooks used are given in Appendix 1; further details are available in the program outline on the BCA website (www.bca.edu.au).

For the Masters degree, 10 or 11 coursework units of study are required plus a 2- or 1-unit Workplace Project Portfolio (WPP), respectively. The aim of WPP is for students to gain practical experience, usually in workplace settings, in the application of knowledge and skills learnt during the coursework of the Masters program. The student provides evidence of having met this goal by presenting a portfolio or thesis made up of project reports and a preface reflecting on their learning, which is then examined and may be awarded a grade. The WPP requirement distinguishes the Masters degree from the Postgraduate Diploma, which can be obtained through the completion of coursework alone with no compulsory project component. Suitable supervision (for both the subject matter and statistical components) and appropriate projects must be available for students embarking on WPP. This is a potential stumbling block for students who do not live in a city that houses one of the universities participating in the BCA, since even if a suitable project and subject matter supervision are available through their workplace, a statistical supervisor may be more difficult to find.

Table 1: Required units of study for each course. Each unit or subject is delivered over one semester and is of length equivalent to a quarter of a full-time study load.

BCA Code	Unit of study	Masters	Post-graduate Diploma	Post-graduate Certificate
Introductory				
EPI	Epidemiology*	✔	✔	✔
MBB	Mathematical Background for Biostatistics	✔	✔	
PDT	Probability and Distribution Theory	✔	✔	
HIS	Health Indicators & Health Surveys			
DMC	Data Management & Statistical Computing	✔	✔	
Intermediate				
PSI	Principles of Statistical Inference	✔	✔	
CLB	Clinical Biostatistics			
DES	Design of Randomized Controlled Trials	✔	✔	
LMR	Linear Models	✔	✔	
CDA	Categorical Data & Generalized Linear Models	✔	✔	
SVA	Survival Analysis	✔		
Advanced				
WPP	Workplace Project Portfolio (1 or 2 units)	✔		
LCD	Longitudinal & Correlated Data			
BAY	Bayesian Statistical Methods			
BIF	Bioinformatics			
ACT	Advanced Clinical Trials			

✔ Unit is compulsory.

* This pre-existing unit is offered by most of the consortium universities as part of their Master of Public Health degrees.

4.1 Student Pathways

An important feature of the BCA program is that it allows entry to students from a range of backgrounds. The eligibility criteria are:

- having already completed an introductory tertiary-level unit in statistics, covering at least the estimation of means and proportions with confidence intervals, and the comparison of means and proportions between two groups;
- a proven aptitude for advanced mathematical work, indicated for example by a high level of achievement in high school mathematics;
- and a Bachelor degree in Statistics, Mathematics, Science, Psychology, Medicine, Pharmacy, Health Sciences or other appropriate discipline from an approved university (or equivalent qualification).

For those with training in disciplines such as health, psychology, or epidemiology, the foundation units MBB, PDT and PSI provide a solid grounding in mathematics, probability and distribution theory and the principles of statistical inference, while those with a recent undergraduate mathematical statistics degree may be exempted from these units.

By the end of 2008 there had been 100 graduates from the BCA program, 50 with Masters degrees, 21 Postgraduate Diplomas and 29 Postgraduate Certificates, and there were currently 306 enrolled in at least one subject. Testimonials of several graduates of the program can be viewed on the BCA website (www.bca.edu.au/stdnt_testimonials.htm).

5. Training the New Generation

5.1 Achievements

In addition to producing 100 graduates so far, the establishment of the BCA has strengthened links among academic biostatisticians in Australia, and between academics and their counterparts working in industry and government. BCA members collaborated to develop the program and now meet regularly by teleconference and face-to-face bi-annually. The BCA has increased the profile of biostatistics in Australia by advertising our program and by organizing and sponsoring workshops, often in association with other conferences such as those for epidemiologists. This has heightened the awareness among potential students of both biostatistics as a profession and the current worldwide shortage of biostatisticians. It has also given us a voice for lobbying government, with the BCA gaining recognition as a professional body by making submissions to national reviews of statistics and mathematics. Another advantage of the program is that it has helped to provide academic teaching positions at the universities involved, thus strengthening their capacity as centers able to supervise PhDs in biostatistics.

In 2004 an independent external review committee, chaired by Professor Louise Ryan from Harvard University, concluded that "The BCA has been successfully established as an outstanding multi-institutional system for developing, strengthening and sustaining Australia's workforce of career biostatisticians. Through intensive coordination of expertise in seven universities and the use of distance education, the BCA is able to offer an educational program in biostatistics that is unique throughout Australia, and indeed the world, in terms of its depth and scope" (Ryan, Jorm & Knuiman, 2004). The national PHERP review in 2005 found that "[T]he BCA is the best example of PHERP Phase III strengthening the basis for high-level and consistent quality education programs" (Durham & Plant, 2005). In February 2007, in a report in the Higher Education section of The Australian newspaper, Professor William Dunsmuir, who is president of the Statistical Society of Australia and head of the statistics department at the University of New South Wales (not a member of the BCA), wrote of "the success of [the] Biostatistics Collaboration of Australia, a graduate training program delivered by [eight] universities and a superb example of how the institutions can work together with the support of government to solve a critical skills shortage" (Dunsmuir, 2007).

So how does the BCA program match up with the training program proposed by DeMets et al. (2006)? From the start we had as our goal that graduates with Masters degrees or Postgraduate Diplomas "should be able to read critically the theoretical and methodology literature" in journals such as Statistics in Medicine. Our program clearly includes all the basic theory and methods listed by DeMets et al. (2006), and the "desirable" additions of clinical trials and epidemiology are compulsory in the BCA program. Through WPP, all Masters students develop their written communication skills, with some choosing to write their project(s) up for publication; some students also gain experience in working as part of a research team and may thus be exposed to research ethics and information privacy training. There is no formal coursework in a biology specialty area, which may not be necessary for those intending to work in public health, nor is there any opportunity for teaching leadership or consulting skills.

The existence of the BCA program has encouraged the development of at least one full-scale training program which has most of the key elements described by DeMets et al. The New South Wales Department of Health (NSW Health) established a Biostatistical Officer Training program with its first intake of two trainees in 2001. This program selects 2 to 5 trainees each year with an Honors degree in Statistics or equivalent from a very competitive field of about 70 applicants from all over Australia. Trainees are employed for 3 years, rotated through 6-month placements in various sections of the broader health service, and are required to enrol in the BCA Master of Biostatistics. To date, 17 NSW Health trainees have graduated with a Master of Biostatistics and another 15 are currently in the training program. Another State health department has recently started a similar program, while students employed in the pharmaceutical industry receive relevant on-the-job training, such as a 2-day workshop on Good Clinical Practice.

The NSW Health training program has attracted students who already have a PhD in statistics and wish to become biostatisticians, one of whom has recently taken up an academic research position. Another student has been appointed to an academic position after completing his Masters degree and is enrolled to do a PhD, demonstrating an alternative way in which the BCA program is helping to train the next generation of academic biostatisticians. As the pharmaceutical industry continues to expand in Australia, it too is looking to the BCA to train some of its employees and is recruiting new staff from those already enrolled in the Masters of Biostatistics degree.

5.2 Opportunities and Challenges

The BCA program has partly fulfilled its mission to strengthen Australia's health workforce capacity by producing well-qualified biostatisticians. Since eligible students anywhere in Australia with an internet connection can enrol in the program, it can be said to have national coverage, but the BCA does not yet have a member university in every State. This can make supervision of the Workplace Project Portfolio difficult. Progress is being made: in 2007 the University of Adelaide joined the consortium giving the BCA a presence in four of the six States. We also have a few students based overseas enrolled in the Postgraduate Diploma, and believe there is scope for us to benefit other countries, especially in the Asia-Pacific region, by making the Masters program available to them if we can make adequate arrangements for supervision of WPP.

The program faces potential competition from within Australia and from overseas education providers. Academic institutions not affiliated with the BCA may choose to offer their own programs, and one university has recently done so. Currently, Australian law prevents most foreign nationals living in Australia from enrolling in the BCA program. On the other hand, any Australian student can enroll in programs offered by distance education by overseas universities. While it is likely that the BCA program will have a cost advantage compared to overseas offerings, its programs need to compete on quality. The quality assurance process of the program is well developed and must meet, at a minimum, the quality requirements of each of its constituent university members; essentially this means there is a "highest common denominator" criterion for any issue. But little systematic work has been done to compare curriculum or outcomes with established courses, either on-campus or distance mode, offered by overseas institutions.

Student retention and degree completions are issues for a program whose current students are mainly enrolled part-time, often working full-time and may have family responsibilities. The structure of the program and method of delivery certainly suit such students, but a Masters degree may take between three and six years to complete, and the risk of dropout over such a time is substantial. There is an opportunity to market the program more effectively to undergraduates nearing completion of their basic degree and to new graduates; such students may be less encumbered than those already in the workforce.

While BCA coursework units are available to suitably prepared doctoral students from any related discipline, the BCA does not yet offer its own doctoral programs, either the traditional Australian (British-style) doctorate by research only or the North American model of advanced coursework plus a research component. The BCA recognizes that advanced training to doctoral and post-doctoral level is an essential component of a national program, especially if we are to contribute to the development of new statistical methods, as called for by DeMets et al. (2006). The current Masters, incorporating the Workplace Project Portfolio, provides a basis for design of a coursework-plus-research doctorate, substantially retaining the distance education framework. However, the role of the BCA in the research doctorate is less clear, as the student-supervisor relationship within each university assumes primary importance. There are opportunities for the BCA to encourage and channel promising Masters students, help match students to supervisors, broker cross-institutional supervisory panels relevant to a student's particular topic, and provide resources and forums for research seminars. The BCA is in a good position to negotiate with Commonwealth and State governments and with industry to provide targeted research degree scholarships. The peak national health research funding body, the National Health and Medical Research Council, provides no specific, strategic support for biostatistics training, although few would deny that availability of statistical skills is a rate-limiting step in national health research productivity.

The program faces challenges to its sustainability. First, an essential element of the BCA is its central secretariat, which is currently funded by a grant from the Australian government. Further support comes from NSW Health and in-kind support from the host institution, the University of Sydney. Change in any of these arrangements, especially the government's role, would have serious consequences for the BCA's viability.

Second, the consortium members have, so far, cooperated on the issues of equity of teaching responsibilities and revenue sharing. To a large extent this reflects the goodwill of the academic representatives on the consortium's Steering Committee; in the small community of academic biostatisticians in Australia, most have known each other for many years. But personnel will change over time, and, on the institutional side, university policies and priorities may also change. In almost every context other than the BCA, universities are in competition with one another for student enrolments, research grants and government funding.

Third, the BCA has done little to market its program - and the opportunities for rewarding careers - to undergraduates in mathematics, statistics, health sciences and related fields. This needs to be remedied. The competition for numerically competent basic graduates to undertake further training and careers in financial services, engineering or physical sciences is keen. The BCA program is only sustainable if it can attract enough good quality students to ensure both viability of the subjects offered and sufficient graduates to maintain support by the stakeholders. Finally, the existing BCA curriculum does not yet adequately cover some emerging areas of biostatistical practice, such as computational methods for data mining. To remain relevant and sustainable the program must carefully consider its curriculum and provide students with opportunities to equip themselves for the future.

6. Summary

In summary, over the last eight years, the BCA has established a novel and credible multi-university model to deliver national training in biostatistics at the Masters level. It must now turn its attention to more advanced training and early career development for academics. The objectives will continue to be to provide an adequate supply of highly skilled academics within Australia, and to facilitate succession planning for the next generation of biostatisticians. We believe this model is one that can be adapted for use in other countries.

Appendix 1: Content and textbooks for units of study

Introductory units

EPI — **Epidemiology**

Content: Measures of frequency and association (e.g. relative risk, attributable risk); main types of study designs – cross-sectional surveys, case-control studies, cohort or follow-up studies, randomized controlled trials; sources of error (chance, bias, confounding); association and causality; evaluating published papers.

Textbook: None

MBB — **Mathematical Background for Biostatistics**

Content: Basic algebra and analysis; exponential functions; calculus; series, limits, approximations and expansions; linear algebra, matrices and determinants; and numerical methods.

Textbook: Anton H, Bivens I, Davis S. *Calculus: early transcendentals version,* 8th edition. Wiley, 2005

PDT — **Probability and Distribution Theory**

Content: Probability, random variables, discrete and continuous distributions, use of calculus to obtain parameters such as mean and variance. Joint distributions, independence, correlation, covariance, marginal and conditional distributions. Distributions of transformations of random variables. Sampling distributions and standard error of an estimator of a parameter, key properties of estimators, large sample results for properties of estimators with emphasis on role of Normal distribution. Numerical simulation and graphing with Stata is used to demonstrate concepts.

Textbook: Wackerly DD, Mendenhall W, Scheaffer RL. Mathematical Statistics with Applications, 7th edition, 2008, Duxbury Press, USA

HIS — **Health Indicators & Health Surveys**

Content: Routinely collected health-related data; quantitative methods in demography, including standardization and life tables; health differentials; design and analysis of population health surveys including the roles of stratification, clustering and weighting.

Textbook: Scheaffer RL, Mendenhall W, Ott RL. *Elementary Survey Sampling.* 6th edition. Wadsworth 2006

DMC — **Data Management & Statistical Computing**

Content: Data management principles and concepts are developed using relational database software (Microsoft Access). Data manipulation, descriptive analyses and interpretation are introduced using SAS and Stata statistical software. Students acquire skills in data display, summary presentation and pattern recognition using these tools.

Textbooks: Cody R, Smith J. *Applied Statistics & the SAS Programming Language.* 5th edition. Prentice Hall 2005

Hills M & De Stavola B. *A Short Introduction to Stata for Biostatistics.* Timberlake 2007

Intermediate units

PSI — **Principles of Statistical Inference**

Content: Key concepts of estimation, and construction of Normal-theory confidence intervals; frequentist theory of estimation including hypothesis tests; methods of inference based on likelihood theory, including use of Fisher and observed information and likelihood ratio; Wald and score tests; introduction to Bayesian approach to inference and to distribution-free statistical methods.

Textbook: Recommended – not compulsory:

Azzalini, A. *Statistical Inference: Based on the Likelihood.* Chapman and Hall, London 1996.

Clayton and Hills. *Statistical Models in Epidemiology.* Oxford University Press, Oxford, 1993.

CLB — **Clinical Biostatistics**

Content: Clinical agreement (kappa statistics, Bland-Altman agreement method, intraclass correlation); diagnostic tests (sensitivity, specificity, predictive values, ROC curves, likelihood ratio); statistical process control (special and common causes of variation, Shewhart, CUSUM and EWMA charts); and systematic reviews (process, estimating treatment effect, assessing heterogeneity, publication bias).

Textbook: None

DES — **Design of Randomized Controlled Trials (RCTs)**

Content: Principles and methods of randomization in controlled trials; treatment allocation, blocking, stratification and allocation concealment; parallel, factorial and crossover designs, including n-of-1 studies; practical issues in sample size determination; intention-to-treat principle; phase I dose finding studies; phase II safety and efficacy studies; interim analyses and early stopping; multiple outcomes/endpoints, multiple tests and subgroup analyses, including adjustment of significance levels and P-values; reporting trial results and use of the CONSORT statement.

Textbook: Piantadosi S. *Clinical Trials a Methodological Perspective, 2nd edition*. John Wiley & Sons 2005

LMR — **Linear Models**

Content: Method of least squares; regression models and related statistical inference; flexible non-

	parametric regression; analysis of covariance to adjust for confounding; multiple regression with matrix algebra; model construction and interpretation (use of dummy variables, parameterization, interaction and transformations); model checking and diagnostics; regression to the mean; handling of baseline values; the analysis of variance; variance components and random effects.
Textbook:	Recommended – not compulsory: Kutner MH, Nachtsheim CJ, Neter J, Li W. *Applied Linear Statistical Models.* 5th edition. McGraw-Hill/Irwin 2005.
CDA	**Categorical Data & Generalized Linear Models**
Content:	Methods for contingency tables: odds ratios, relative risks, chi-squared tests for independence, Mantel-Haenszel methods for stratified tables, and methods for paired data. The exponential family of distributions; generalized linear models (GLMs), and parameter estimation for GLMs. Inference for GLMs – including the use of score, Wald and deviance statistics for confidence intervals and hypothesis tests, and residuals. Binary variables and logistic regression models – including methods for assessing model adequacy. Nominal and ordinal logistic regression for categorical response variables with more than two categories. Count data: Poisson regression.
Textbook:	None
SVA	**Survival Analysis**
Content:	Kaplan-Meier life tables; logrank test to compare two or more groups; Cox's proportional hazards regression model; checking the proportional hazards assumption; time-dependent covariates; multiple or recurrent events; sample size calculations for survival studies.
Textbook:	Hosmer D W, Lemeshow S, May S. *Applied Survival Analysis: Regression modeling of time to event data*. 2nd edition. Wiley Interscience 2008. Recommended – not compulsory: Cleves M, Gould W, Gutierrez R. *An Introduction to Survival Analysis Using Stata,* 2004. Stata Press - http://survey-design.com.au/

Advanced units

WPP	**Workplace Project Portfolio (1 or 2 units)**
Content:	The aim of this unit is that the student gains practical experience, usually in a workplace setting, in the application of knowledge and skills learnt during the coursework of the Masters program. The student provides evidence of having met this goal by presenting a portfolio, made up of a preface and project report(s), for examination by one examiner from the home university and one from another BCA university.
Textbook:	None
LCD	**Longitudinal & Correlated Data**
Content:	Paired data; effect of non-independence on comparisons within and between clusters of observations; methods for continuous outcomes: normal mixed effects (hierarchical or multilevel) models and generalized estimating equations (GEE); role and limitations of repeated measures ANOVA; methods for discrete data: GEE and generalized linear mixed models (GLMM); methods for count data.
Textbook:	Recommended – not compulsory: Fitzmaurice G, Laird N, Ware J. Applied Longitudinal Analysis. John Wiley and Sons, 2004.
BAY	**Bayesian Statistical Methods**
Content:	Simple one-parameter models with conjugate prior distributions; standard models containing two or more parameters, including specifics for the normal location-scale model; the role of non-informative prior distributions; the relationship between Bayesian methods and standard "classical" approaches to statistics, especially those based on likelihood methods; computational techniques for use in Bayesian analysis, especially the use of simulation from posterior distributions, with emphasis on the WinBUGS package as a practical tool; application of Bayesian methods for fitting hierarchical models to complex data structures.
Textbook:	Gelman, A. , Carlin, JB, Stern, HS and Rubin, DB. *Bayesian Data Analysis*, 2nd edition. Chapman and Hall, 2003.
BIF	**Bioinformatics**
Content:	Biology basics; population genetics; web-based tools, data sources and data retrieval; analysis of single and multiple DNA or protein sequences; hidden Markov Models and their applications; evolutionary models; phylogenetic trees; analysis of microarrays; functional genomics; use of R.
Textbook:	Durbin R, Eddy S, Krogh A, Mitchison G. *Biological Sequence Analysis: Probabilistic models of proteins and nucleic acids*. Cambridge University Press, 1998.
ACT	**Advanced Clinical Trials**
Content:	Methods in RCTs for determining: stopping rules for interim analyses (O'Brien-Fleming, Peto), spending functions, stochastic curtailment; statistical principles encountered in relation to aspects of regulatory guidelines (ICH, FDA, EMEA), and related to reports prepared for data safety and monitoring committees (DSMC); design and analysis of cross-over trials (period effects, interactions); equivalence and non-inferiority trials; problems of defining and using surrogate endpoints as alternatives to direct clinical outcomes
Textbook:	Recommended – not compulsory: Senn S. *Cross-over trials in clinical research,* 2nd edition. Wiley, 2002.

Jennison C. and B.W. Turnbull. *Group sequential methods with applications to clinical trials*. Chapman & Hall, 1999.

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