Teaching medical statistics to undergraduate medical students: what is taught and what is really useful for a medical professional? A report of the Education Committee of the Italian Society of Medical Statistics and Clinical Epidemiology (SISMEC)

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ABSTRACT

Background: There is a large heterogeneity among the courses of medical statistics in Italian Medical Schools.
Aims: (1) To describe issues that are dealt with in the statistics undergraduate medical courses in Italian medical Schools. (2) To investigate which methodological topics are deemed as more useful for the education of undergraduate medical students by clinical teachers.
Methods: (1) An online questionnaire, covering the qualifying teaching issues of medical statistics, was sent to all academic biostatisticians, asking what they were teaching to undergraduate medical students. The reference year was 2015-2016. Undergraduate medical courses were the statistical units. (2) A second survey involved teachers of other medical disciplines with institutional roles, asking to score the usefulness for medical education of a number of topics concerning medical statistics, on a 5-point Likert scale. Only descriptive analyses were performed.
Results: Fifty-two (96%) case report forms (CRF) were returned from teachers of medical statistics. Most statistical and epidemiological topics were taught except comparison of >2 groups, impact of biases and standardization of rates. Conversely, issues of clinical epidemiology were neglected in about half of degree courses.
Thirty-three (31%) CRFs were returned from clinical teachers. The percentage of issues deemed very useful or essential ranged from 57% to 94%, with higher scores for those referring to critical assessment of the literature.
Conclusions: More extensive coverage of clinical epidemiology issues is needed to meet the demand of physicians, as responsible consumers of quantitative research. As biostatisticians we should operate to increase the homogeneity of medical statistics teaching in medical undergraduates' education

Key words: Medical education, Biostatistics, Medical statistics, Clinical epidemiology

INTRODUCTION

The main task of medical doctors is to take decisions in a state of uncertainty. Thus, undergraduate medical students have to cope with it, being aware of the probabilistic foundations of knowledge, and should realize that the statistical way of thinking is a parallel way to become a better medical doctor, both in the traditional clinical activity and community level interventions.

What statistics should be taught to undergraduate medical students has been matter of discussion for long time [1]. Meetings for teachers of statistics in medicine are held annually in United Kingdom since 1979 [2]. It has been repeatedly emphasized that 'most doctors will be consumers rather than producers of quantitative research', and possibly their best use of statistical methods is in the critical appraisal of medical literature [3].

In the second half of the '80s an intense debate took place in Italy on reforming the undergraduate medical curricula (D.P.R. n. 95/1986) [4], that led to profound changes, and identified a number of disciplines whose content should be the core of the modern clinical practice. Medical statistics was among them. The reform law also introduced the 'Integrated course' as the teaching unit, meaning that more disciplines, and more teachers, could concur to pursue the pre-defined objectives within the same teaching unit. Moreover, some disciplines, mainly methodological, could give their contribution across several integrated courses. Educational credits, according to the Educational Credit Transfer System (ECTS) as adopted within the European Community, had to be assigned to the integrated courses on the whole and to the individual contributing disciplines.

Subsequent administrative acts heightened the self-government of the Universities, that modeled number and value of the integrated courses (and of disciplines within them) in the undergraduate medical curricula in different ways, leading to large heterogeneity. As for Medical statistics, a survey presented at the 8th national Congress of the Italian Society of Medical Statistics and Clinical Epidemiology (SISMEC, Torino 16-19 September 2015) showed that the educational credits assigned to the Medical Statistics discipline ranged from 1 to 9, suggesting that several inconsistencies among the covered topics should be expected. Therefore, we decided to investigate what teachers of medical statistics actually teach to Italian medical students and which statistical issues the clinicians think would be useful to medical students.

In this paper we report the results of two companion surveys promoted by the Education Committee of SISMEC. The first one involved all Italian teachers of medical statistics and described the actual biostatistics offer in medical education; the other one addressed teachers of other disciplines, trying to characterize the expected biostatistics demand in preparing skilled medical students.

METHODS

Both surveys were performed from May to October 2017.

The first survey addressed the teachers of medical statistics in the Italian medical Schools and investigated the statistical issues dealt with in the undergraduate medical courses. A quite detailed questionnaire was sent to all teachers of medical statistics, covering all the qualifying teaching issues of medical statistics previously identified by the Education Committee of SISMEC in 2008 (SISMEC Conference on Teaching Medical Statistics, Milano, September 16, 2008).

The English translation of the questionnaire is reported in supplementary Table S1. The teaching issues concerned nine main domains: (1) demography, (2) descriptive epidemiology, (3) descriptive statistics, (4) statistical inference, (5) analytical epidemiology, (6) prognosis, (7) diagnostic accuracy, (8) treatment efficacy, and (9) evidence-based medicine (EBM). All issues were submitted as learning objectives, with verbs suggesting the requested level of knowledge. The questionnaire was filled using a Google online survey form.

The reference academic year was 2015-2016. The statistical unit was the degree course in medicine; thus the form had to be completed for every course if several undergraduate medical courses were scheduled within the same medical school. This choice was prompted by the fact that different teachers could give priority to different issues. Further, since methodological issues may be addressed at different times, each form would report on all the teaching issues even if pursued in different integrated courses (and possibly by different teachers).

We also asked whether methodological issues were addressed by the biostatistician her/himself or by teachers of other academic disciplines. For non Italian readers it is worth clarifying here that Italian academic teachers/researchers are identified by 50 academic disciplines ('settori scientifico-disciplinari') and that the discipline 'medical statistics' is actually given code MED/01. People entrusted in teaching medical statistics within medical courses are mostly identified with that code. Further, since biostatisticians are lacking in some medical schools and some issues overlap with other academic disciplines, some objectives might be addressed by teachers of other disciplines (e.g clinicians or hygienists) within the same undergraduate medical course. For the sake of simplicity we will use below the term 'biostatistician' to designate teachers pertaining to the academic discipline 'medical statistics' (MED/01) and the term 'other than biostatistician' to designate teachers of other academic disciplines .

The second survey aimed to understand whether what is taught is actually deemed as useful for undergraduate medical students. A simpler questionnaire, asking to score the usefulness for medical education of a number of topics of medical statistics, was sent to 106

institutional representatives of the academic medical world: the Presidents 'pro tempore' of the 50 academic medical disciplines and 56 Deans for Education of the medical courses. Six main domains were investigated: (1) epidemiology and demography, (2) biostatistics, (3) prognosis, (4) diagnosis, (5) efficacy, and (6) EBM. We chose to use a simpler form with a reduced number of more general topics in the hope to increase compliance. For every topic, the sole question was 'How much is this skill useful for a medical professional', allowing an answer on a 5-point Likert scale, ranging from 'not at all' to 'essential'. Further to every topic addressed in the questionnaire, we associated one or more appropriate elementary teaching units of the core curriculum defined by the Conference of Deans for Education of medical courses, in order to suggest the medical framework for which it could be applicable (http://presidenti-medicina.it/core-curriculum/). The English translation of the questionnaire is reported in supplementary Table S2.

For both surveys two recall messages were sent to improve compliance. Only simple descriptive analyses were performed.

RESULTS

1. Which statistical issues are dealt with in the undergraduate medical courses?

Fifty-two (96%) case report forms (CRF) were returned from teachers of medical statistics in 54 undergraduate medical courses in 35 medical schools. In two other medical schools CRF was not due, either because the statistics course was not present in the medical curriculum (Perugia) or because no statistics course was held in 2015-16, due to ongoing transition between old and new curricula (Palermo). In 46 (88%) courses the teacher was a biostatistician, while in the other 6 cases she/he came from other disciplines: hygiene (4), occupational medicine (1) and physics (1).

The number of educational credits ranged from 1 to 9, the median being 5 (interquartile range, IQR, 3 to 6). Accordingly, the median time assigned to medical statistics teaching was 48 hours (IQR 30 to 60, range 8 to 96). In 18 (35%) medical courses the medical statistics teaching was distributed in different years. Thirty-two different biostatistics textbooks were suggested to the students, but in most cases alternative textbooks could be used without stringent preferences.

Main results of the biostatisticians' survey are reported in Figure 1. As expected, most statistical and epidemiological issues were dealt with in the degree courses. As for the statistics domains, two specific topics were scarcely carried out, i.e. comparison tests of more than 2 groups) and biases, while standardization of rates was often overlooked in the epidemiology field. Issues not dealt with mainly referred to clinical epidemiology; EBM and prognosis evaluation were not tackled at all in about half of the medical degree courses (Figure 1). Epidemiology and demography issues were often tackled by non biostatisticians, mainly by hygiene teachers, while, when taught, clinical epidemiology issues were mainly dealt with by biostatisticians (Figure 1).

2. Which statistical issues do the clinicians think would be useful to medical students?

Only 33/106 (31%) CRFs were returned from clinical teachers. Main results are reported in Figure 2. Although almost all topics were taken in high consideration, the highest rank was given to the critical appraisal of scientific literature and to the assessment of burden of diseases; these topics were graded as essential, or very useful, by 94.4% and 91.2% of responders, respectively.

DISCUSSION

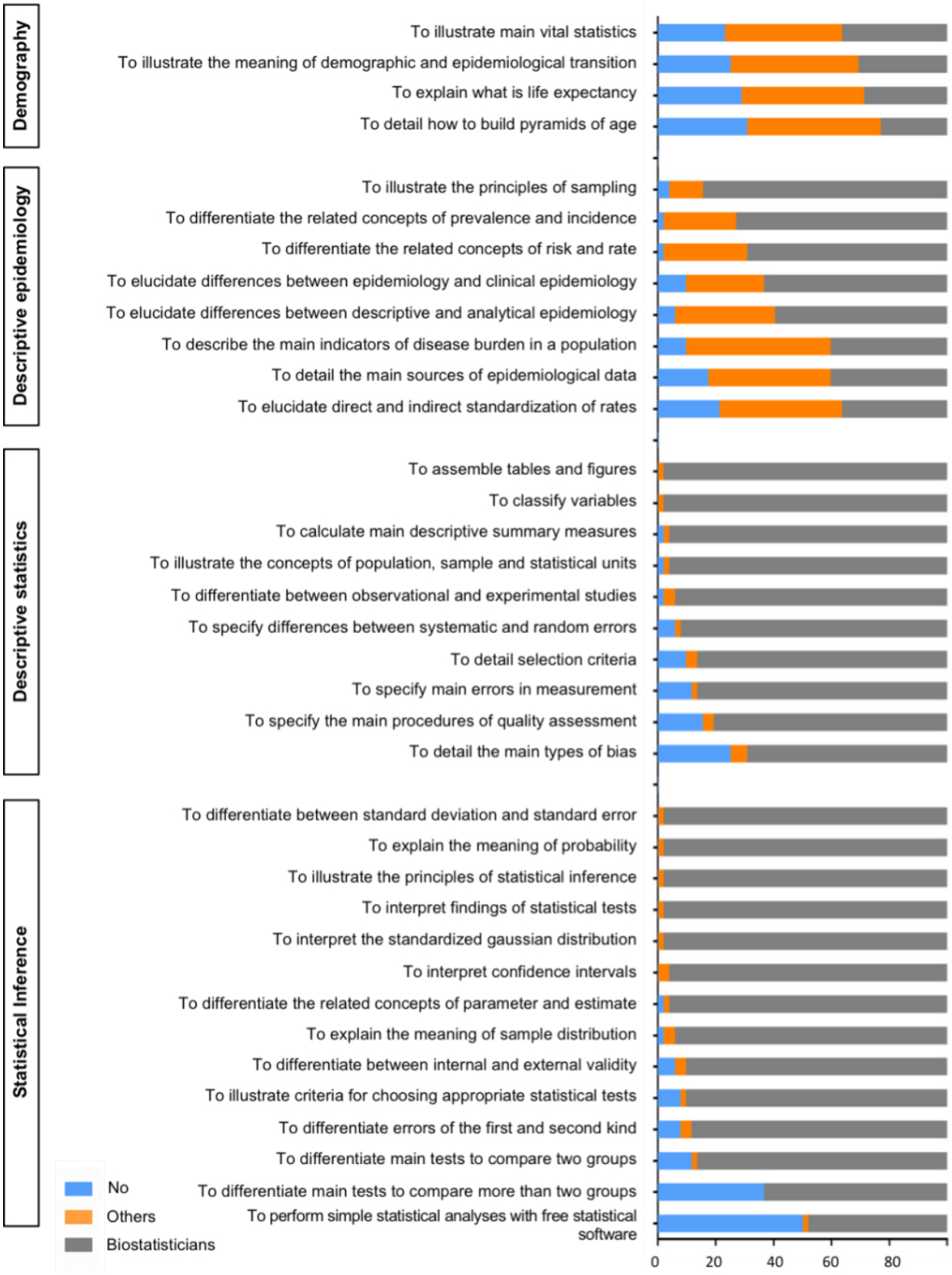
We postulate that quantitative methods, both statistical and epidemiological, parallel clinical methods in building clinical reasoning, and contribute to train better doctors. Clinical practice indeed would become clinical routine and would not be in the best interest of patients if doctors would not be able to think logically, to read critically, to act mindfully. Doctors should be able to motivate their decisions, integrating their clinical experience with the best available information and the patient's values and preferences [5].Notwithstanding criticisms [6] the paradigm of EBM (Evidence-based medicine) still works [7]; looking for reliable evidence is to be improved [8], but still remains a key issue for appropriate clinical decisions. Statistical reasoning is a crucial tool to critically interpret evidence for making decisions.

As consumers of quantitative research doctors should be aware of the statistical and epidemiological principles underpinning medical research whose results outline the reference framework for clinical decisions and help to counteract the possibly deleterious information coming from inadequate sources [9] (e.g. the webidence-based [10] or the propaganda-based [11] medicine). It is deplorable that a number of medical students still learn techniques, but lack an organized approach to understanding the structure of medical problems and are unable to put methods in context.

Nonetheless, as doctors, medical students will also become manufacturers of clinical information, and they should be aware of the flaws arising from bad quality data. What is the right balance between the need to know the fundamentals of a methodologically sounded medical information and the need to not increase the 'obesity' of medical curricula?

From our surveys it appears that methods underlying

FIGURE 1. Percentages of responses from teachers of medical statistics to the question: Was the specific learning objective tackled at any time throughout the degree course? Colors correspond to possible responses: blue: not done; orange: yes by teachers other than biostatistician; grey; yes by biostatisticians. Questions are ordered within domains



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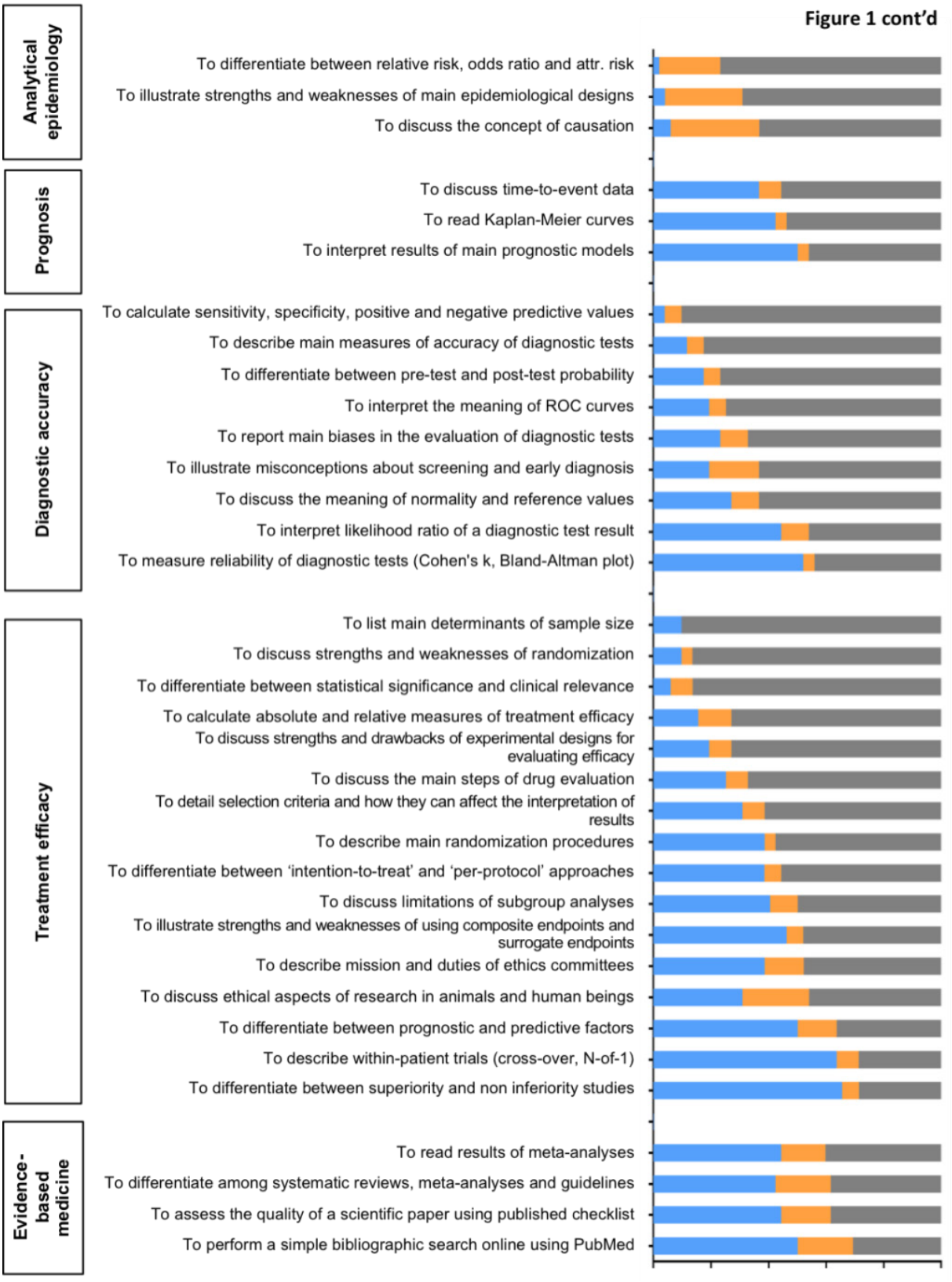
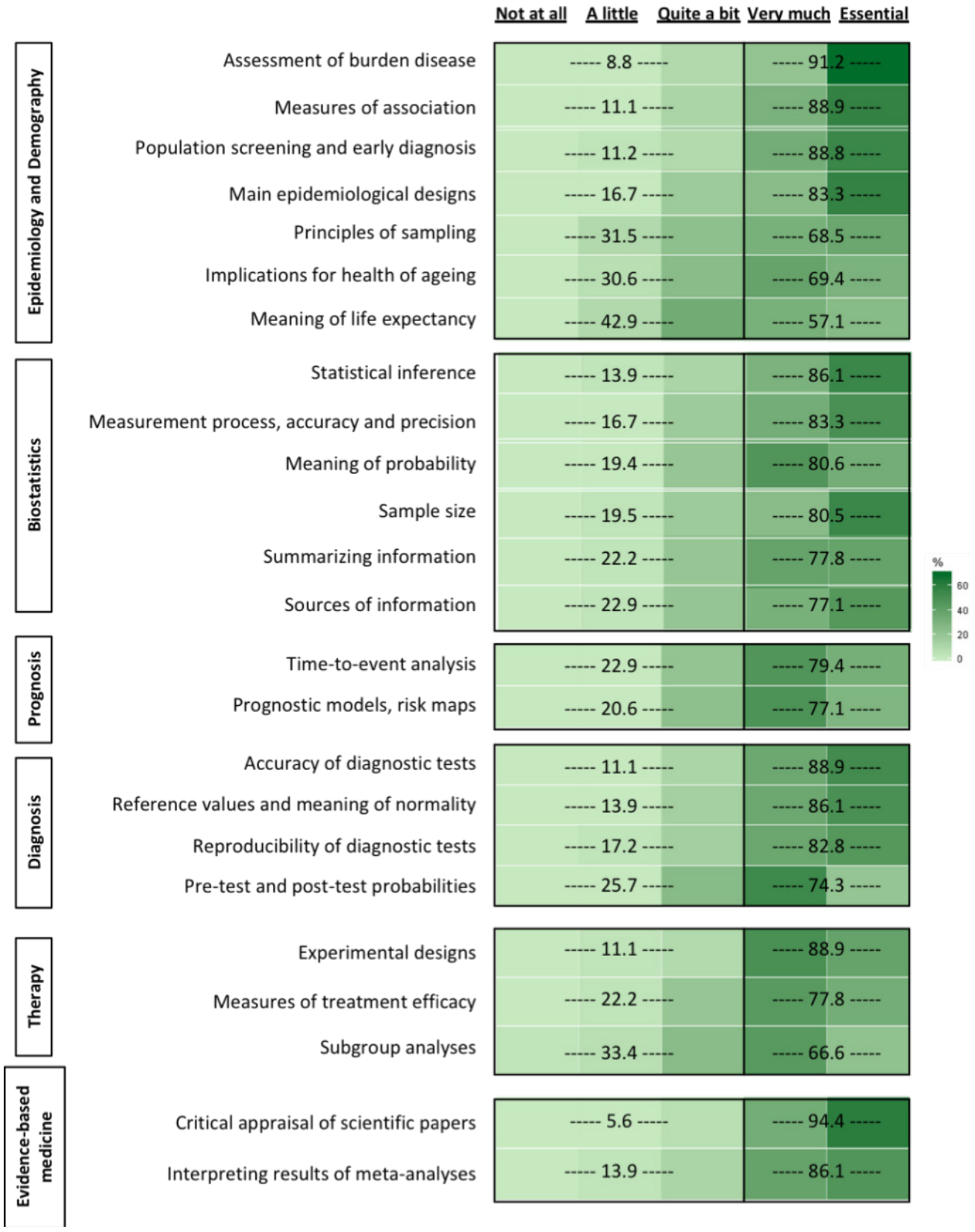


FIGURE 2. Heat map of responses of clinical teachers to the question: Is the skill useful for medical undergraduate education?



clinical epidemiology are frequently overlooked in medical courses, the unique exception being simpler measures of diagnostic accuracy. There are two alternative explanations. These issues are dealt with in other courses, but teachers of medical statistics are not aware of it; if this were true, there would be an educational flaw, and better integration should be pursued in order to improve harmonization among different disciplines. Alternatively, these issues are not tackled at all during the whole course, possibly because they are not given enough priority; if so, medical students are deprived of proper tools for critically evaluating medical information.

Consistently, with cautions due to the small size and possible selection bias of our sample, teachers of

TABLE S1. Questionnaire for teachers of Medical Statistics: specific learning objectives

SPECIFIC LEARNING OBJECTIVES
Domain: Demography **General aim: To understand implications for health of ageing in Western countries**
To illustrate demographic and epidemiological transition
To detail how to build pyramids of age
To explain what is life expectancy
To illustrate the main vital statistics
Domain: Descriptive epidemiology **General aim: To report how disease frequency and needs for health may be measured at community level**
To differentiate between epidemiology and clinical epidemiology
To differentiate between descriptive and analytical epidemiology
To detail the main sources of epidemiological data
To illustrate the principles of sampling
To describe the main indicators of disease burden in a population
To differentiate between prevalence and incidence
To differentiate between risk and rate
To differentiate between direct and indirect standardization of rates
Domain: Descriptive statistics **General aim: To use main statistical methods to report biomedical information**
To differentiate between observational and experimental studies
To specify the differences between systematic and random errors
To detail the main types of bias and how they can affect the interpretation of results
To illustrate the concepts of population, sample and statistical units
To detail selection criteria and how they can affect the interpretation of results
To classify variables
To differentiate between precision and accuracy of measurements
To specify the main procedures of data quality assessment (consistency, correctness, completeness)
To assemble tables and figures
To interpret the main descriptive summary measures (centrality, dispersion, association)
Domain: Statistical Inference **General aim: To use more common statistical methods to infer conclusions from research findings**
To differentiate between internal and external validity
To explain the meaning of probability
To differentiate between parameter and estimate
To explain the meaning of sample distribution
To differentiate between standard deviation and standard error
To interpret the standardized gaussian distribution
To illustrate the principles of statistical inference
To interpret confidence intervals
To interpret the findings of statistical tests
To differentiate between the errors of the first and second kind
To illustrate the criteria for choosing the appropriate statistical tests
To differentiate between the main tests to compare two groups
To differentiate between the main tests to compare more than two groups
To perform simple statistical analyses with free statistical software

The same question for all issues was: Was it dealt with in your degree course? Three answers were allowed: No/yes/yes by teachers of other academic disciplines.

other medical disciplines ask for better comprehension of medical literature, thus emphasizing the need for understanding methodological aspects of papers rather than just looking at the arithmetic aspects of statistical techniques.

A shift toward critical appraisal of medical literature using problem-based questions would be in order, even refining teaching priorities when time is limited. We need a change of perspective. When teaching critical attitudes towards numerical information, we should focus

TABLE S1 (CONTINUED). Questionnaire for teachers of Medical Statistics: specific learning objectives

SPECIFIC LEARNING OBJECTIVES
Domain: Analytical epidemiology **General aim: To detail strengths and weaknesses of main epidemiological designs to compare measures of disease occurrence**
To illustrate strengths and weaknesses of the main epidemiological designs (cohort, case-control, cross-sectional, ecological) To differentiate between relative risk, odds ratio and attributable risk To discuss the concept of causation
Domain: Prognosis **General aim: To apply main statistical methods to evaluate prognosis**
To discuss time-to-event data To read Kaplan-Meier curves To interpret results of the main prognostic models
Domain: Diagnostic accuracy **General aim: To apply main statistical methods to evaluate diagnostic accuracy**
To discuss the meaning of normality and reference values To report the main biases in the evaluation of diagnostic tests To describe the main measures of accuracy of diagnostic tests To calculate sensitivity, specificity, positive and negative predictive value To differentiate between pre-test and post-test probability To interpret likelihood ratio of a diagnostic test result To interpret the meaning of ROC curves To assess reliability of diagnostic tests (Cohen's k, Bland-Altman plot) To illustrate misconceptions about screening and early diagnosis
Domain: Treatment efficacy **General aim: To apply main statistical methods to evaluate treatment efficacy**
To discuss the main steps of drug evaluation To discuss strengths and drawbacks of experimental designs for evaluating efficacy (single-arm trials, historical controls, randomized clinical trials) To discuss strengths and weaknesses of randomization To describe the main randomization procedures (simple, stratified, permuted blocks) To differentiate between superiority and non inferiority studies To describe within-patient trials (cross-over, N-of-1) To illustrate strengths and weaknesses of using composite endpoints and surrogate endpoints To discuss selection criteria and how they can affect the interpretation of results To list the main determinants of sample size To differentiate between 'intention-to-treat' and 'per-protocol' approaches To calculate the main absolute and relative measures of treatment efficacy To differentiate between statistical significance and clinical relevance To discuss the limitations of subgroup analyses To differentiate between prognostic and predictive (effect-modifier) factors To discuss the ethical aspects of research in animals and human beings To describe mission and duties of the ethics committees
Domain: Evidence-based medicine **General aim: To critically appraise Evidence-Based Medicine (EBM)**
To differentiate between systematic reviews, meta-analyses and guidelines To interpret results of meta-analyses To perform a simple bibliographic search online using PubMed To assess the quality of a scientific paper using published checklists (CONSORT, STROBE, STARD, PRISMA)

The same question for all issues was: Was it dealt with in your degree course? Three answers were allowed: No/yes/yes by teachers of other academic disciplines.

on the aspects that heavily interfere with the correctness of conclusions, and could affect the appropriateness of medical decisions. Signs of old-style courses could be the little weight given to detecting and understanding biases, that counteracts the clinicians' attitude to look for p-values only, and to subgroup analyses, where the danger of p-hacking is not always realized, and the difference between confirmatory and exploratory questions seems disregarded. Some issues overlap with other disciplines thus a more stringent interaction with other teachers is required. The final learning assessment should also be focused on competencies rather than cognitions, and should be aligned with the teaching objectives.

A possible barrier to change is that teachers

TABLE S2. Questionnaire on clinicians' opinions on the usefulness of medical statistical issues in medical education.

CLINICAL LEARNING OBJECTIVES AND MEDICAL STATISTICS SKILLS [*CORE CURRICULUM*]
Domain: Epidemiology and Demography **General aim: To identify health problem in the whole population**
Implications for health of ageing in Western countries [287, 291, 707]
Meaning of life expectancy [417]
Principles of sampling [539,549]
Main epidemiological designs (cross-sectional, case-control, cohort, ecological) [610]
Assessment of burden disease (prevalence, incidence, risk, rate) [358, 361, 569]
Measures of association (relative risk, rate ratio, odds ratio) [355, 363, 532, 557, 578]
Domain: Biostatistics **General aim: To use main statistical methods to report biomedical information**
Measurement process, random and systematic errors, accuracy and precision [2]
Sources of information in epidemiological and clinical research [383, 418, 547, 554, 577]
Summarizing information (tables, figures, descriptive statistics) [560, 613, 614]
Meaning of probability [552,553, 604]
Statistical inference (confidence intervals, significance tests) [548,549, 573]
Sample size [539]
Domain: Prognosis **General aim: To critically evaluate prognosis**
Prognostic models, risk maps [378, 536, 570]
Time-to-event analysis (survival curves) [417, 565]
Domain: Diagnosis **General aim: To critically evaluate diagnostic testing**
Reference values and meaning of normality [1128, 1131]
Measurement of accuracy of diagnostic tests (sensitivity, specificity, predictive values, likelihood ratio, ROC curves [421, 1138]
Measurement of reproducibility of diagnostic tests [608]
Pre-test and post-test probabilities [537]
Population screening and early diagnosis [356, 357, 419]
Domain: Efficacy **General aim: To critically evaluate the efficacy of medical interventions**
Experimental designs (randomized/non randomized, superiority/non inferiority, parallel/cross-over, open label/double blind) [426, 566,604]
Absolute and relative measures of treatment efficacy [566]
Subgroup analyses [566]
Domain: Evidence-based medicine **General aim: To critically appraise Evidence-Based Medicine (EBM) for clinical decisions**
Interpreting results of systematic reviews or meta-analyses [365, 538, 559, 563, 567, 568, 607, 619]
Critical appraisal of scientific papers [540, 619,620]

Numbers within square brackets correspond to the elementary teaching units reported in the core curriculum of the Italian Conference of Deans for Education of Medical courses, referring to the specific issue (http://presidenti-medicina.it/core-curriculum/).
The same question for all issues was: In your opinion is the skill useful for medical education? Five ordered possible answers were allowed: (i) not at all, (ii) a little, (iii) quite a bit, (iv) very much, (v) essential

of medical statistics have heterogeneous background, ranging from statistics to mathematics to physics to medicine to pharmacy. Therefore what they bring in the medical courses is their own training approach, rather than the effort to fit the real needs of medical education. We are aware that changing our education routines might be perceived as some loss of identity, but the reward is a more effective integration of medical statistics in medical undergraduates' education thus reinforcing our role of teachers in medical schools and increasing visibility of our discipline. Changes in teaching would not affect at all our role of biostatisticians as researchers in the medical community.

Accordingly focus on research skills could more usefully be delayed to post-graduate courses or limited to a reduced number of interested people.

We are wondering also whether such an approach is feasible in the first or second year of medical courses when usually students face with issues without immediate clinical value, and EBM and medical statistics are perceived as abstract disciplines, without implications for their medical knowledge [12].

Main limitation of this study is that we did not ask for level of knowledge or competency requested for each statistical issue. All issues were submitted as learning objectives, with verbs suggesting the appropriate level of knowledge, and that choice prevented us to assess the actual heterogeneity of deepness of the teaching offer. A further limitations is the low clinicians' response rate; we proposed a simpler questionnaire to increase compliance but in vain, and we cannot exclude a responders' selection bias.

CONCLUSIONS

In this paper we were asking two questions: 'What are Italian teachers of medical statistics actually teaching to medical students?' and 'What do Italian clinicians expect from teachers of medical statistics?' Results of the two surveys substantiated that many steps have been taken in the right direction by teachers of medical statistics in Italian undergraduate medical courses but there is still a long way to go to meet the demand of physicians as responsible consumers of quantitative research. Homogeneity of learning objectives among medical schools should be improved through a better coordination of biostatisticians for a more effective involvement of the medical statistics discipline in medical undergraduates' education.

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