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COMMENTARY

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Statistical advising: Professional development opportunities for the biostatistician

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1 | INTRODUCTION

In contrast to the theoretical statistician, the biostatistician needs *broad* knowledge and understanding of applied statistics, which has led to the development of specific training programs for medical statistics and biostatistics over the last 50 years.[1] In addition, the job of the biostatistician is multi-disciplinary and collaborative in its essence,[2,3] meaning that

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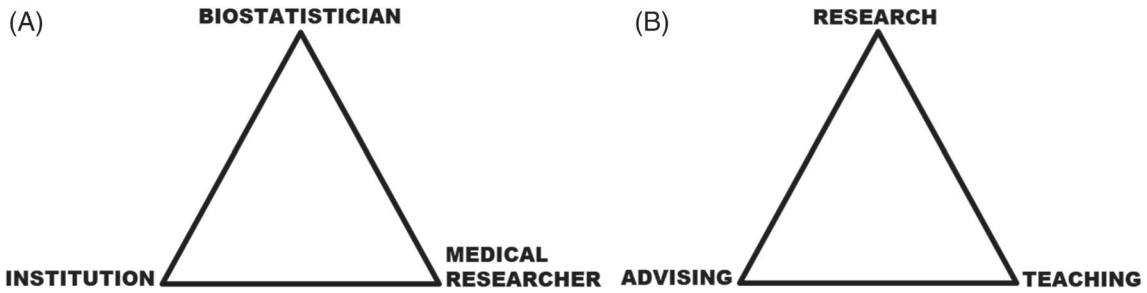

FIGURE 1 The golden triangles of (A) biostatistical advising and (B) the components of a biostatistician's career

training and practical experience in interdisciplinary research and communication of statistics to biomedical researchers is required.

In this article, we show that this can be achieved by continued education on the job, which is crucial for the professional development of the biostatistician and progression of the medical research field. At the same time, we discuss how interdisciplinary collaboration and biostatistical advising can play a crucial role for the *academic research career* of the biostatistician. We understand career development as the professional development of the biostatistician in all aspects (advising, research, teaching), and outline how the right framing of statistical advising can help the biostatistician draw from specialist knowledge to develop new research questions, address roles and responsibilities in collaborative research, and develop independence and leadership skills.

We define biostatistical advising as structured or unstructured statistical support in biomedical research offered in an academic context that can range from short one-time meetings to long-term collaborations between the biostatistician and the other researcher(s). The ADVICE|2018 conference, the first international conference on biostatistical advising, held in Oslo, September 9 to 11, 2018, was attended by 109 participants from 18 countries across 4 continents (with the majority from Europe). This article is a synthesis of the ideas and points of view that were discussed among the conference participants, and further explored by the authors of the manuscript. A key topic that emerged during the conference was lack of recognition of the opportunities that biostatistical advising can bring to the biostatistician's professional development. Our impression is that biostatistical advising is often perceived as a time-consuming interruptive task with little direct benefit for the biostatistician's research career.

By the end of this article, we hope to have convinced the reader that biostatistical advising should be considered a key activity in the biostatistician's professional development and with the appropriate frameworks is beneficial for both the biostatistician and the biomedical research process. We explore what the organizing institute, the medical researcher, and the biostatistician himself/herself can do to boost opportunities and how all parties benefit, ultimately leading to better, reproducible medical research.

The article is targeted to both institutions and individual biostatisticians, both senior and junior, and is presented as a narrative discussion supported by relevant information in various text boxes. In Appendices A and B, we provide examples of training for biostatistical advising, and an overview of important resources and strategies for biostatistical advising.

2 | LABELS MATTER

Across different institutions and countries, many different labels are used for the process of statistical advising and the people involved (Box 1). We argue that these labels matter, because they imply different views on the relationship between the biostatistician and the biomedical researcher, and on the advising process and the biostatistician's role in the scientific process in general.[4] Ultimately, they also influence the impact biostatistical advising can have on the professional development of the biostatistician. For example, the terms "support," "service," and "help" imply that the role of the biostatistician is limited to providing a reply to a specific request for help (eg, a methodological advice or sample size calculation). "Consulting" is often used in the context of a professional service where statistical support is provided against payment. "Supervision," on the other hand, is more commonly used in an academic context, where the statistician is a senior researcher acting as a formal or informal academic supervisor for a student or junior researcher.

BOX 1 Terms used for the process of involvement of a biostatistician in academic biomedical research projects and the people involved

Terms used for the process of biostatistical advising	• Advising • Consulting • Help • Research collaboration • Support • Supervision • Service
Terms used for the adviser	• Adviser • Biostatistician/Statistician • Consultant • (Biostatistical) Researcher • Service provider • Technician • Data scientist/Data analyst • (Statistical) Supervisor • Colleague • Collaborator
Terms used for the advisee	• Advisee • Client • Clinician • Domain expert • Field expert • (Biomedical) Researcher • (Biomedical) Student • Colleague • Collaborator

In Norway, where the ADVICE|2018 conference was held, the word "veiledning" is commonly used to describe biostatistical advising in an academic context, which is translated to English as "guidance, instruction, direction, **advice**, tutorials (academic), supervision (academic)" (ordnett.no, version 4.0.20). Throughout this article, we will use the term "advising" for all types of involvement of a biostatistician in academic biomedical research projects. Even though "(biostatistical) consulting" is commonly used, we avoid this term here to remove the professional connotation of providing a service against payment, and to focus on the type of advising activities most likely to have a positive impact on the research career path of the biostatistician.

3 | TYPES OF ADVISING AND RELATED OPPORTUNITIES FOR THE BIOSTATISTICIAN'S PROFESSIONAL DEVELOPMENT

Biostatisticians should ideally be involved from the very beginning of a biomedical research collaboration, when research teams are built and projects are planned,[4,5] but in our experience often are first involved at later stages, for example, when a project is already ongoing and data collection is completed. Here we make the case that changing

this pattern is important not only for the research process but also for the professional development of the biostatistician.

3.1 | Three types of advising

Statistical advising varies with respect to time spent on a project and type of activity undertaken—from high-level strategic advice, for example, on the analysis plan or writing of the manuscript, to performing the actual data analysis.

We summarize these dimensions into three types of advising,[6] which should be seen as archetypical and are often mixed in working environments. The role of advising and its impact on the biostatistician's research career are different in each of these types.

1. Advising in a single or a few *advising session(s)* (sometimes called consulting service), where the advisee poses questions on statistical aspects in a particular project and the adviser discusses possible solutions but does not further engage in the project. These advising sessions are an excellent opportunity for early career biostatisticians to learn how to bridge the gap from statistical theory to statistical practice. They are good starting points for networking, that is, to learn about different research environments and research activities at the statistician's institute. They can also provide a first point of contact with potential biomedical research partners and may therefore constitute the starting point for collaboration. Therefore, the earlier in the scientific process such an advising session is held, the better.
2. By *single-project collaboration or support* we mean that a biostatistician contributes to a project at the design stage and/or the analysis stage over a longer period of time. On this level, parts of the research project are at least partly led by the biostatistician or a team of biostatisticians, for example, developing the experimental design and statistical methodology, authoring parts of the study protocol, setting up analysis plans, performing the statistical analyses, discussing results with the study team, and preparing methods and the manuscript. The peer-review process of scientific journals will typically require the biostatistician to address questions raised by reviewers. Biostatisticians can also be involved in the writing of grant proposals. Such project collaborations can be very useful to increase visibility and establish a good reputation among biomedical research partners, co-author publications and learn important leadership and communication skills in the context of interdisciplinary research.
3. A *long-term collaboration or partnership* may be established when the biostatistician has become very familiar with the research domain. In this situation, the biostatistician is an integral part of the research team, and may develop their own research ideas which put the subject of the research into new light. For example, the biostatistician may find that a suitable modification of a statistical method can enhance the clinical interpretability of the research. The novel problem-driven methodology can be published in a biostatistical journal and is as important as the biomedical value of the substantive research. Long-term collaborations and partnerships often lead to acquiring research grants as a team and publishing several papers together. We consider long-term collaboration as potentially the most fruitful way of interdisciplinary collaboration, because the experts of all fields are included from the very beginning, working together to reach a common goal.[7] Biostatisticians in such long-term collaborations might be at later stages in their careers, since the development of these partnerships takes time and investment in professional contacts. But more experienced statisticians can promote the inclusion of more junior colleagues in such collaborations under guidance and thus provide career development opportunities for them.

3.2 | Mutual respect

No matter how a biostatistician is involved in the scientific process, the most important requirement of successful interdisciplinary collaboration, in our opinion, is mutual respect.[8] All collaborators have to recognize each other as important contributors to the scientific process and success of a project.[9] The biostatistician has to be recognized as a researcher with their own line of expertise within the field of statistics, not simply as a technician.[4] Effective and good communication promotes mutual respect between the parties.[9] However, to be respected, one must provide a certain level of wholeheartedness and enthusiasm for interdisciplinary collaboration, and make genuine connections with the research and partners. This should be expected from all partners.

4 | INSTITUTIONAL ORGANIZATION OF ADVISING TO PROMOTE PROFESSIONAL DEVELOPMENT

The organization of advising (whether formalized or not) within an institution can impact the scientific process and career opportunities for biostatisticians. We believe that institutions should organize advising such that it is possible for biostatisticians to build long-term collaborations and mutual trust, develop deep understanding of a research field, leading to a more focused CV. Excellent articles and textbooks have been published over the years on various aspects of organizing biostatistical advising and collaboration, discussing best practices,[8,10,11] quality control and standardization of the advising process,[11] strategies for avoiding common problems[8,9,12] (see also Table B1 in Appendix B with resources for biostatistical advisers) and for building and supporting centralized units.[13] These are all means by which an organization can improve and standardize the advising process. However, how the organization can improve the impact of advising on the professional development of biostatisticians has been less discussed in the literature.

Biostatisticians, whether working in an academic biostatistical advising unit or embedded in a broader academic biomedical context, typically conduct their own research, do advising part-time, and have the opportunity to network via single advising sessions and establish long-term collaborations (Box 2). The biostatistician's professional development can be promoted by working within an organized advising unit where resources and requests can be matched quite flexibly, and by being surrounded by peers. In practice, it may be easier to build a biostatistical research career in this context. The embedded biostatistician, on the other hand, is presented with an important opportunity to build deep knowledge of a particular biomedical domain, which may catalyze long-term collaboration and the development of novel biostatistical methods and their applications. Work in an isolated fee-per task advising center might be less beneficial for the use of biostatistical advising for a biostatistician's research-based career. However, if performed part-time in addition to research time, this might also help to identify relevant methodological research questions and initiate collaborations.

BOX 2 Different ways of organizing biostatistical advising

There are different ways to organize biostatistical advising, depending on funding, autonomy and organizational structure of the academic institute:

(a) **Academic advising unit:** Here, biostatistical advising is provided as a substructure in an existing statistical research institute. This can take any form from an organized advising service to the informal availability of biostatisticians for questions or collaborations.
(b) **Embedded statistician:** The embedded statistician is located in a biomedical academic unit and gives independent support upon request. This person is usually employed as the sole or one of few biostatisticians in a non-statistical research environment.
(c) **Fee-per task advising center:** For example, a clinical trials unit. These centers are formed with the sole purpose to do biostatistical advising as a service provider without other scientific obligations by their employees.

4.1 | Institutional support for the biostatistician's professional development

We believe that the institution has the responsibility to provide an environment that allows the biostatistician to have the time and freedom needed to succeed in their research career. This can be achieved by clever matching and prioritization of advising work, working actively toward efficient (eg, software) solutions for routine tasks, and offering basic statistical courses for biomedical researchers. For organized academic advising units, we believe that there is value in having a clear policy with regards to the integration of advising and research activities, for example through a mission statement.[14]

For good matching and prioritization decisions, Perkins et al[10] recommended the following questions:

1. Is the project of high impact, for example, scientifically, clinically or societally?
2. Is there funding for the biostatistical effort required for the project?
3. Is the project likely to result in a co-authored publication?

4. Does the unit have biostatisticians with the expertise needed for the project?
5. Is this support for a student project or has otherwise an educational component?

We also propose to add the following question to this list:

6. Does the project align well with the research interests of the biostatistician(s) who are potentially available for the task?

Based on these questions, a decision on prioritization can be made, matched against the mission, for example, which types of support are offered and to whom they are offered, resources of the unit, and the expertise and interests of the individual biostatistician. Good matching and prioritization make advising efficient—and thereby frees up time, for example, for research.

It is important to create an environment where statistician colleagues can easily exchange experiences with advising projects both formally and informally. This can help to resolve problems, raise awareness of potential dangers, share good practices, and available resources such as guidelines and technical solutions (see Table B1 in Appendix B), and to create an environment of shared values and practices.

4.2 | The funding model for advising can affect the biostatistician's career opportunities

Different forms of funding may create different conflicts of interest. Therefore, an effective funding model for a biostatistical advising unit may require a diverse portfolio that could include, for example, core institutional support, research grant support, support from biomedical academic units, and direct payment by the advisee. A diverse portfolio results in greater stability and flexibility to accommodate different types of projects and funding levels and diminishes the risk implied by economic dependencies. Stable funding can guarantee continued advising in the case of job changes, taking into account the interests of the advisee and the adviser. The benefits of a mixed funding model apply at the individual level as well; biostatisticians who are funded by several mechanisms will not only have the opportunity to engage in a broader range of research and other activities such as training and mentoring, but also have more job satisfaction and security over the long run.

4.3 | Organizations should offer shared research, teaching, and advising positions

For many positions at academic institutions, a combination of advising, teaching, and biostatistical research is quite common. While the teaching responsibilities are likely explicitly described, the advising component may be less clearly defined. We think being explicit about advising responsibilities is crucial both for high quality recruitment and for the individual statistician's professional development. We consider it important that institutions take the potential role of advising in the continued education of their employees into account when planning how to organize advising and communicate clearly how advising duties will be aligned with professional development goals. For example, the institution may offer positions with 1:1 research to advising or teaching, as is done at several of the authors' institutions. This is in line with the ASA statement on Statistics as a Scientific Discipline and Practical Implications for the Evaluation of Faculty Excellence,[15] which states that collaborative research should be valued by employers, for example, when hiring or considering promotion; and that collaborative research should be included in offer letters and role descriptions as an expectation, and that these terms should be discussed regularly during a career.

Another way is to offer advising roles to PhD students, either as an additional volunteering task, as a replacement for teaching, or by extending their PhD project by, say, 1 year in return for a 1-year advising duty spread out over the total time of the PhD project. The PhD student gains relevant experience and meets new collaborators/projects, the institution gets advising done, and both get to try out whether the advising role may be of interest in the longer term.

4.4 | Mentorship and training

An important role of later-career statisticians is to mentor early career colleagues and to introduce them to their advising activities, research networks, and support them in establishing their own research partnerships.[16-18] The institution can aid in this process by formalizing mentorship.

One of the first steps of recognizing advising as a pillar in the biostatistician's career is to actually train new statisticians in advising. From our experience, it appears that most biostatistical advisers are informally trained on the job, learning advising by doing advising. While experience is an essential part of development, we believe that a more effective training program would include the five steps of preparation, practice, doing, reflecting, and mentoring others.[11] That is, to be given support and opportunity to prepare and practice advising tasks before being fully involved in advising projects, and to have space for reflection—also by mentoring new advisers and discussing with peers—afterwards. Appendix A provides examples of how statisticians are trained to become biostatistical advisers at seven institutes in the United States, Europe, and Africa (see also Jaki et al[19]). We note that even though there is a wide variety in how formalized the training is between these institutes, all programs include aspects of the five steps.

5 | ETHICAL ASPECTS: RESPONSIBILITIES AND OPPORTUNITIES FOR BIOSTATISTICIANS

5.1 | Manuscript authorship

Co-authorships are an important measure of success, both for the individual biostatistician and for the institution providing the advising service. For biostatisticians, publications from their methodological research often seem to be prioritized when they apply for academic positions, but we would like to make the point that co-authorships resulting from advising activities can also be important for professional development, because they demonstrate strength of interdisciplinary collaboration skills and can also include advanced methodological techniques. In this context, it is good to remember that co-authorship is not the only personal benefit from advising for the development of a biostatistician's research career. Other benefits include learning opportunities (eg, about cutting edge biomedical research in general, or relevant interesting biomedical research questions that align well with their interests in statistical methodology in specific), building a collaboration network, and developing teaching and leadership skills.

Co-authorship implies full responsibility and accountability for the manuscript and the conduct of the study. In interdisciplinary collaborations this is only possible if there is mutual trust and respect between project partners and if all co-authors are willing to listen to and respect the unique expertise of each partner (see Section 3,3.2). Lack of mutual respect can lead to various potential ethical dilemmas with regards to manuscript authorship specific to biostatisticians in interdisciplinary research (see Box 3). We argue that all such dilemmas can be resolved by following the authorship rules outlined in the International Committee of Medical Journal Editors (ICMJE) recommendations for roles and responsibilities for authorship ("Vancouver Convention"; VC) (see Boxes 3 and 4).

BOX 3 Examples for ethical dilemmas related to manuscript co-authorship and how to solve them with the ICMJE recommendations for roles and responsibilities for authorship ("Vancouver Convention")[20,21]

Dilemma 1: The advising biostatistician has contributed sufficiently to merit co-authorship but is not included in the author list, for example because the biomedical partners believe that contributions as part of a paid-for service do not justify co-authorship.

Dilemma 2: The biomedical partners were hesitant to include a statistician in their research, because they believed they were able to do the analyses themselves. However, this was not the case. When a statistician eventually was included in the analyses, interpreting the results and writing the paper, he/she was refused a co-authorship because he/she was not involved in the design of the study.

Solution to Dilemmas 1 and 2: The first Vancouver Convention (VC) criterion is relevant as one should be invited to be co-author if one has performed data analysis. If the biostatistician then chooses to contribute and fulfill VC criteria 2 to 4, they should be a co-author. Note that according to the VC, payment for data analysis, for example, from a consulting service, cannot be a reason to be excluded from co-authorship.

Dilemma 3: The biomedical partners (to indicate that the manuscript was assessed and approved by a statistician) or institution hosting the advising service (eg, because of financial benefits for the institution) would like the biostatistician to be co-author, but the biostatistician thinks that he/she did not contribute enough to warrant co-authorship.

Solution Dilemma 3: Also here, the first VC criterion can be used that clearly states which contributions are required to be eligible as co-author.

Dilemma 4: The biomedical partners or institution hosting the advising service would like the biostatistician to be co-author but the biostatistician does not want to be affiliated with the publication because he/she is concerned about lack of methodological rigor or misleading conclusions being drawn from the statistical analysis.

Solution to Dilemma 4: VC criteria 3 and 4 clearly state that as a co-author the biostatistician needs to give full approval of the final manuscript and feel comfortable with agreeing to be accountable for all aspects of the work. In a first place, the biostatistician should communicate with the other authors and try to solve the methodological issues. If this does not work, the biostatistician can withdraw co-authorship (VC criteria 3 and 4).

Note: In case of serious scientific misconduct, the biostatistician should also alert the appropriate authorities at the research institution such as the scientific ombud, research integrity officer, or institutional review board.

BOX 4 ICMJE recommendations for roles and responsibilities for authorship ("Vancouver Convention")[20,21]

The ICMJE recommends that authorship should be based on the following four criteria:

1. Substantial contributions to the conception or design of the work; OR the acquisition, analysis, or interpretation of data for the work; AND
2. Drafting the work OR revising it critically for important intellectual content; AND
3. Final approval of the version to be published; AND
4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

These criteria are intended to reserve the status of authorship for those who deserve credit and can take responsibility for the work. They are not intended for use as a means to disqualify colleagues from authorship who otherwise meet authorship criteria by denying them the opportunity to meet criterion #2 or 3.

Further, the VC guidelines provide a good basis for the development of a research career of a biostatistician and are aligned well with institutional level interests of statistical advising centers. We recommend discussing co-authorship early in the advising process and to document agreements to prevent and help resolve conflicts.

5.2 | Impact on Good Scientific Practice

Good Scientific Practice (GSP)[22] guidelines are a helpful resource in the context of co-authorship, as they specify what responsibilities entail. The change in perspective that we are promoting throughout this article, from the statistician as a technical expert to being an integral partner in the research process, will help the biostatistician to take responsibility for GSP and to ensure that ethical aspects of the project are addressed.[3]

Naturally, biostatisticians have expertise with respect to GSP in the areas that are directly related to the statistical aspects of a study, such as study design, data collection and statistical methods for data analysis, but also interpretation and reporting of results—including appropriate reporting of uncertainty in estimates and careful discussion of the findings, in particular with emphasis on model assumptions and study limitations.[4]

In addition, we argue here that the core expertise of statisticians extends also to other GSP aspects, in particular to research transparency and reproducibility.[23] This is because of the biostatistician's expertise in making the underlying model framework and data analysis steps explicit and specifying model assumptions and limitations, writing predefined statistical analysis plans and dynamic reporting. These transparency measures are part of the solution to the reproducibility crisis in biomedical research,[24,25] by reducing the common problems of data dredging (p-hacking)[26] and HARKing,[27] especially when combined with the open science approach of making all methods and results publicly available.[28,29]

6 | CONCLUSION

In this article, we have presented the biostatistical advising process as an essential component of the professional development and continued education of the biostatistician. With the proper institutional support and mutual respect between all individuals involved, statistical advising provides important opportunities for the biostatistician to gain experience and develop skills in interdisciplinary research, communication and development of novel research questions. This ultimately benefits not only the biostatistician but also biomedical research.

We propose two triangles for the biostatistician's professional development (Figure 1). In each triangle the three elements need to be in good *balance*; the first triangle represents the three involved partners in the biostatistical advising process, the biostatistician, the medical researcher and the organizing institution (Figure 1A), and the second illustrates the interplay between biostatistical advising, teaching statistics, and research in methodology for promoting professional development (Figure 1B).

We recommend careful choice of labels used for the biostatistical advising process. For example, in a long-term collaboration, refer to the biostatistician as collaborator, colleague or partner rather than statistical support, to better reflect the actual roles and responsibilities.

We think that different types of statistical advising (single advising session, short-term single project support, long-term collaboration) present different opportunities for professional development for the biostatistician. Starting with chances for expanding one's network and improving communication skills with single advising sessions, this can progress to long-term and fruitful collaborations between the biostatistician and biomedical researchers using the strength of each of the partners involved throughout the research process. The biostatistician can be inspired to identify novel methodological research questions and develop new statistical methods, contributing to problem-driven methodology development.

The institution can support the biostatistician's professional development and continued education by good prioritization and matching of projects, which could be implemented by bundling thematically linked projects. Such a structure has the potential to increase efficiency and quality of statistical advice, while at the same time benefit career development through deepened collaborations. For biostatisticians, we see advising as one of the main arenas for developing collaborative research skills and establishing new collaborative research projects. Institutions should prioritize offering joint research and advising positions, much like is done with teaching, rather than separating out positions for full-time advising. Institutions can recognize advising as a pillar in the biostatistician's career by offering training both via mentorship and formal training programs.

Following the framework of the VC guidelines helps to align collaborative research and co-authorships toward a fruitful career and avoids ethical dilemmas. Because many of the skills of the biostatistician directly relate to the core principles of GSP, the biostatistician is well set to take up a leadership role in establishing GSP in collaborative research.

We have argued for the need to recognize the continued education opportunities presented to the biostatistician through the advising process, and for the critical role it plays in the biostatistician's professional development. We hope that academic institutions will increasingly recognize the critical importance of implementing biostatistical advising in combination with research and teaching, to the mutual benefit of the biostatistician, the institute and the biomedical research process as a whole.

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APPENDIX A. EXAMPLES OF TRAINING FOR BIOSTATISTICAL ADVISING SKILLS

A.1 Laboratory for Interdisciplinary Statistical Analysis (LISA) at the University of Colorado Boulder, USA

At LISA graduate and undergraduate students from statistics, data science, and applied mathematics programs undergo a five-step training program including preparation, practice, doing, reflecting, and mentoring. Students prepare to become statistical advisers by adopting the attitude of collaboration,[30] observing LISA advising sessions, and learning the theory and best practices of collaboration—specifically the ASCCR Frame for collaboration.[11] Students practice advising via

mock sessions. Most real LISA advising sessions are conducted by an experienced and a novice adviser, so that the novice can receive mentoring, coaching, and feedback. Trainees also engage in structured reflection. During Video Coaching and Feedback Sessions, a small group (5-7) of students and faculty review clips from a video-recorded advising session to determine what went well and what could be improved. Students complete this training program by mentoring new novice advisers.

A.2 Stellenbosch University, MSc in Biostatistics, South Africa

In South Africa, where biostatisticians are extremely scarce, Stellenbosch University's MSc in Biostatistics teaches advising through a module on Biostatistical Consultation and Collaboration. This was developed in response to a meeting of Sub-Saharan African Biostatisticians in 2014, which identified the need to help train biostatisticians to improve their "soft" skills including collaboration, communication and consulting skills.[31] The course was based on an existing successful module at McMaster University, Canada,[32] and consists of lectures and practical sessions with video coaching. A three-month internship where students are exposed to advising under supervision provides experiential learning.

A.3 University of Freiburg, Germany

Institutions not involved in training programs for biostatisticians will rarely be able to offer modules as described above to their students or junior staff. At the University of Freiburg, Germany, the approach to training technically skilled juniors, for example, with a degree in mathematics or stochastics, in biostatistical advising includes: teaching medical students in courses on epidemiology and evidence-based medicine; gradually increasing involvement in applied statistical modeling projects; observing advising sessions with senior staff; seeking help before advising sessions based on the description of the advising request, and reflecting on sessions in weekly feedback rounds with senior advisers; reviewing feedback from advisees.

A.4 Oslo Centre for Biostatistics and Epidemiology (OCBE), Norway

OCBE, a joint center integrating the research and advising activities of the Department of Biostatistics at the University of Oslo and the Department of Research Support Services at Oslo University Hospital, coordinates its advising activities via an organized advising unit, where new advising clients apply centrally via a website and are assigned to advisers based on required expertise and availability. Early-career biostatisticians (PhD students and post-docs) are asked to contribute to advising in well-defined projects with limited numbers of hours. New advisers participate in advising sessions led by more experienced advisers before being assigned their own advising projects. This guided form of "learning by doing" is supplemented by a regular "advising-on-advising" seminar series where typical challenges with advising are discussed and by a mentoring program focused on advising activities.

A.5 University of Manchester, UK

At the University of Manchester, UK, advising skills are also being developed in the context of teaching statistics. Many non-statisticians teach elements of statistics on programs in biology, medicine, and health. Allowing these educators to access expert statistical advice when they plan and deliver their teaching benefits both the educators and their students. Access to such advice is facilitated by pairing educators with early career statisticians through a buddying scheme. The scheme provides the early career statisticians with structure and support for the process of advising the educator and benefits them through experiencing the design, delivery, and evaluation of teaching with a more-experienced colleague.

A.6 University of Zurich, Switzerland

At the Department of Biostatistics at University of Zurich different forms of biostatistical advising and collaboration are offered, from 1-hour biostatistical advising by junior and senior academic biostatisticians for medical students to biostatistical advising as well as contractual data analysis for clinical researchers. In the latter case, senior biostatisticians are usually involved or supervise the work of juniors. In our Master's program in Biostatistics, we teach communication skills and offer a "Statistical Consulting" module, in which a Biostatistics undergraduate, a supervisor from the Department of Biostatistics and a clinical collaborator work together on a research project for the duration of a semester. We also organize part-time positions at departments of the University Hospital Zurich (20%-100% FTE) in which the biostatistician, closely linked to the Department of Biostatistics, is involved in teaching activities and is supervised by senior biostatistician colleagues.

A.7 University of Vienna and Medical University of Vienna

The Bachelor's program in Statistics at the University of Vienna has a seminar on statistical consulting. At the Medical University of Vienna, part-time positions are offered to MSc-level statistics students, with the main responsibility to support clinical collaboration projects under supervision of senior statisticians—which is also a model for teaching advising and developing staff. In addition, internships are offered to high-school students through the Austrian Research Promotion Agency where the students participate in a consulting project.

APPENDIX B. RESOURCES FOR BIOSTATISTICAL ADVISERS

TABLE B1 An overview of some resources available to biostatistical advisers

Title	Source	Notes
Guidelines on Good Scientific Practice		
European Code of Conduct for Research Integrity	https://ec.europa.eu/research/participants/data/ref/h2020/other/hi/h2020-ethics_code-of-conduct_en.pdf	
ICH guidelines, for example, on Good Clinical Practice (E6) and Statistical Principles in Clinical Trials (E9)	https://www.ich.org https://www.ema.europa.eu/en/ich-e6-r2-good-clinical-practice https://www.ema.europa.eu/en/ich-e9-statistical-principles-clinical-trials	
ICJME Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (commonly referred to as the Vancouver Convention)	http://www.icmje.org/icmje-recommendations.pdf	
Guidelines on Reporting and Analysis		
EQUATOR Networks	https://www.equator-network.org/	Reporting guidelines, statements and checklists for all types of studies, for example: • CONSORT: Randomized trials • PRISMA: Systematic reviews • REMARK: Biomarker studies • STROBE: Observational studies • SPIRIT: Study protocols • STARD/TRIPOD: Diagnostic and prognostic studies
STRATOS Initiative	http://www.stratos-initiative.org/	An initiative to strengthen analytical thinking for observational studies including a homepage with resources for guidance.
Resources for transparency and reproducible research		
Version control systems (e.g., git, SVN)		Systems responsible for managing changes to computer programs and documents.
Dynamic document tools (Sweave, knitr, RMarkdown for R, dyndoc/putdocx/putpdf/putexcel for Stata)	• https://yihui.org/knitr/ • vignette("Sweave") in R console • help dyndoc … in Stata console	Combines statistical analysis scripts with output report. Rerunning the script with new data updates the report.

(Continues)

TABLE B1 (Continued)

Title	Source	Notes
Pipeline tools (eg, GNU Make, SnakeMake)	https://www.gnu.org/software/make/ https://snakemake.github.io	Specify data analysis workflows (with several software tools) by a set of rules. Each rule is an analysis step defining how to obtain output files from input files.
Public repositories for publishing codes, data sets and statistical analysis plans (e.g., github, osf).	https://github.com, https://osf.io	
Resources for teaching statistics in an advising context		
Statistics notes, British Medical Journal	https://www.bmj.com/specialties/statistics-notes	Series of short papers introducing statistical topics, with focus on concepts rather than maths. The series is ongoing.
Tutorials, Statistics in Medicine	https://onlinelibrary.wiley.com/page/journal/10970258/homepage/tutorials.htm	Series of tutorials introducing statistical topics in detail including worked examples. The series is ongoing.
References for advising and communication practices		
The ASCCR Framework for Learning Essential Collaboration Skills	Vance and Smith[11]	
Sprechen Sie Statistik?	Frøslie and Røislien[33]	
Successful Research Supervision: Advising Students Doing Research	Lee[34]	
Some statistical software solutions for advising (focusing on bioinformatics applications)		
Open-source statistical software projects for bioinformatics using R	• Bioconductor project (https://www.bioconductor.org)[35] with extensive guidance for non-statistician users, for example, via courses, package vignettes and workflows • Chipster platform (https://chipster.csc.fi)[36]	
Tools for non-statistician users from the Biometric Research Program, National Cancer Institute	https://brb.nci.nih.gov/programdownload/default.htm	