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Interpretation of clinical data and hypothesis testing with the aid of self-collected data from physiology laboratory courses: a teaching approach for medical students

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INTRODUCTION

More than 50 million scientific articles were published between 1665 and 2009 (4), with millions more expected every year (6). This incomprehensible number accounts for scientific articles alone and does not encompass various "pseudo-scientific" information and articles that are spread, without any peer review process, by social media and blogs, thereby generating a potential source of misleading information. Therefore, without a solid scientific background, it is becoming increasingly difficult to distinguish between useful and misleading information. Moreover, clinical studies are crucial for advancing medical knowledge and improving patient care, where we think that medical students should get the opportunity early to gain experience working and operating with them.

Indeed, medical students are exposed during their studies to an abundance of scientific literature, and, in front of this wealth of information, they should keep a critical eye on the many published studies to ensure that a new approach is safe and useful. However, the understanding of medical students with regard to study design, clinical data gathering, data verification, and proper use of statistics seems often limited. To familiarize medical students early in their education with the objectives and complexity of clinical research, we have developed in our physiology curriculum a practical and economical way to teach clinical data gathering and hypothesis testing. Therefore, we present here a newly introduced and recently established physiology module for medical students to illustrate how to *1*) scientifically collect, interpret, and treat anthropometric, metabolic, and cardiovascular data derived from practical lessons during their physiology courses; and to *2*) build and test a clinically relevant hypothesis based on the initial data collected.

Conception and rationale. In our current medical curriculum, which spans over 6 yr in a fully bilingual (French and German) environment and with a frequent use of English, medical students follow classes of physiology over their first 2 yr, the first year of which is devoted to an introduction to systems, general cellular physiology, and the chapters of nerve and muscle, with a small number of corresponding student practical courses. The second year, however, constitutes the core of the physiology curriculum, with in-depth study of all of the systems concerning the human body. In parallel to the theoretical lectures and the sessions of problem-based learning, students follow in the course of a full semester various practical sessions devoted to classical physiological experiments. The majority of these experiments are actually performed on the students themselves, with the help of fellow colleagues, and are depicted in Fig. 1. Physiological derivations or even pathologies were rarely encountered during the experiments and concerned primarily electrocardiography ("unusual" heart axis and heart rhythm troubles), hemodynamic (high blood pressure and orthostatic dysregulations), and respiration (signs for obstructive lung diseases). Students were then advised to refer to a member of the faculty who is a qualified medical doctor for further advice.

All of these data, which are collected in our standard curriculum and used for illustrating physiological concepts, can thus be used for the establishment of a large, anonymous clinical database to which the answers from a questionnaire on personal characteristics and lifestyles are added. Our Institutional Curriculum Board, which is responsible for the medical curriculum and its teaching activities and developments, authorized our proposed data entry, its compilation, and accessibility.

Establishing the clinical database. Figure 2 depicts a flow chart, which condenses and summarizes all of the different stages of our presented practical module called Scientific Thinking and Methodology (STM). Students were briefly introduced to the nature and purpose of this practical course during the first lecture of the third semester in September. On their first appearance at the practical course, each student had to pick a unique personal number out of a box and was advised to keep it confidential. Subsequently, students collected self-evaluated data from the various practical physiology courses, i.e., *1*) electrocardiogram, auscultation, and pulse wave velocity; *2*) basic hemodynamic principles with orthostasis; *3*) metabolism (with anthropometry); *4*) respiration; and *5*) renal function testing, from September to December. At the end of the practical courses and after an introductory lecture, each student entered his or her collected data anonymously in a password-protected dedicated database with the aforementioned chosen number. Moreover, this database additionally contained a detailed questionnaire in which, for example,

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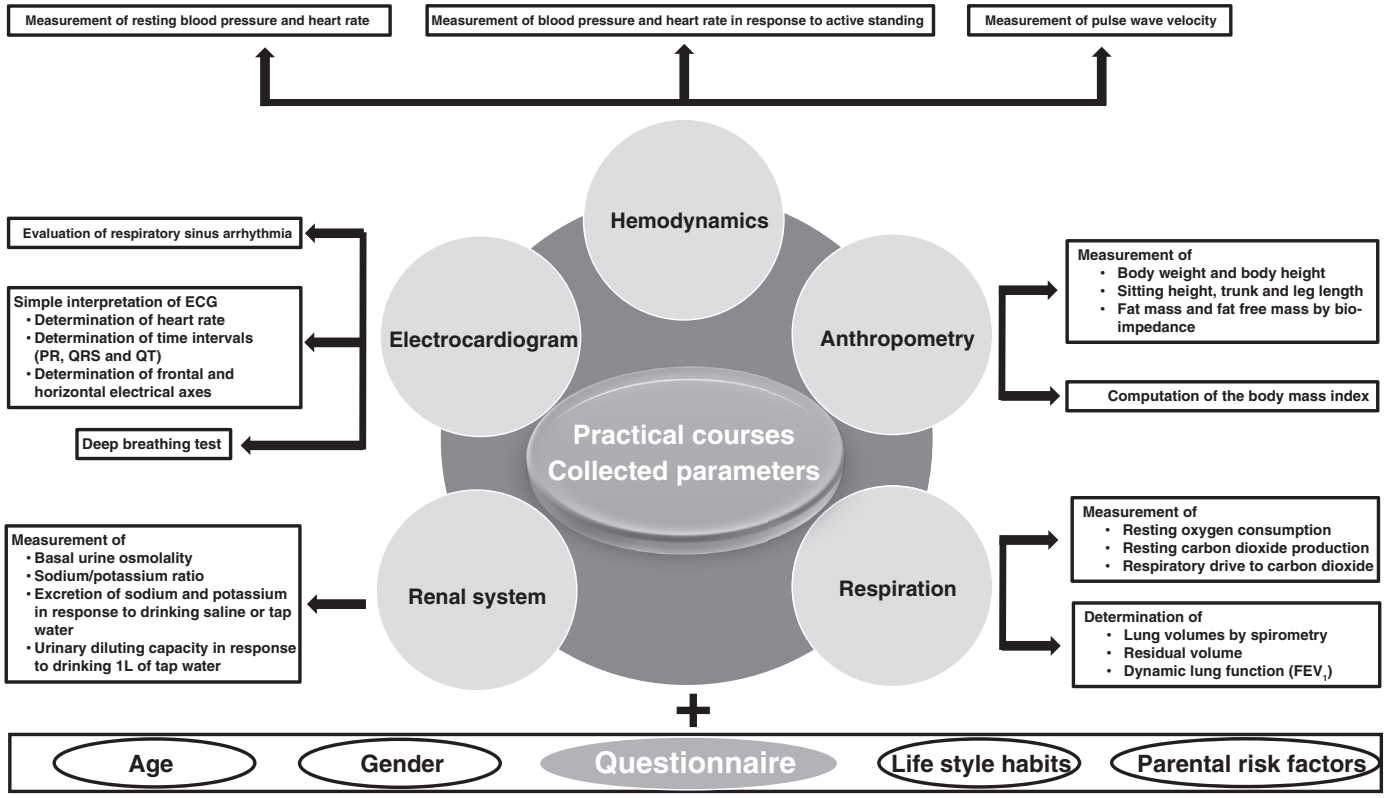

Fig. 1. Parameters and variables collected and assessed by medical students on themselves during and after practical courses in physiology. ECG, electrocardiogram; FEV_1, forced expiratory volume in 1 s.

information on lifestyle habits, personal nutrition, and parental cardiovascular risk factors was collected. A total of 111 medical students participated in this novel teaching initiative. Of these, 95 (85.6%) students anonymously entered all of the requested data in the STM database, whereas 14 (12.6%) students did not enter any data. Two (1.8%) students partially entered data. However, due to the anonymization of data entry, no consequences arose for those not entering data.

Building and testing a refutable hypothesis. Students were instructed to *1*) collect and work with self-evaluated data; *2*) acquire basic statistical knowledge to, first, judge the quality and reliability of the data, and, second, test their preliminary hypothesis; *3*) present their results in meaningful tables and/or figures; and *4*) discuss/defend their findings. We addressed the issue concerning the credibility of source material (for example, scientific literature from PubMed versus blogs or forums), during an introductory lecture before opening the database. Students were instructed to rely on peer-reviewed publications for the literature search and had to provide justification for the credibility of their findings. All students were familiarized in the third semester with the necessary statistics to test their initial hypothesis appropriately. Immediately after closing the database, students were asked to form groups by themselves (minimum: 3; maximum: 5 students per group) and to develop a study question that was based on self-collected data from which a refutable hypothesis had to be generated (Table 1 provides a selection of submitted study questions that were subsequently translated to a refutable hypothesis).

We have chosen for our students the form of a poster, with the subheadings introduction, methods, results, and discussion, to solve the problem of working on a self-developed and clinically relevant hypothesis. Since none of our students had previous experience with a similar teaching approach or the creation of such a poster, we made a self-created poster checklist available to them and advised the students to stick to this defined frame. Moreover, each group received structured feedback (~20 min), which was, together with the checklist, well received by the students. Additionally, and based on the content of their posters, students had to perform an oral presentation in front of their colleagues. Poster and oral presentations took place during a symposium spanning two afternoons, where posters were mounted in a public place. However, we would like to encourage potential interested parties to create more flexibility in terms of the presentation of results, where the instructor could decide, together with the group of students, the manner of presentation (e.g., written report or an oral report), as well as the requirement of statistics needed to generate results.

Assessment of achieved learning. The instructor was advised to carry out an assessment of achieved learning by the conduction of a structured feedback session, where each student group arranged a meeting with the instructor as soon as they finished working on their poster. At the beginning of each feedback session, the instructor judged the received poster version and provided a preliminary mark that was not revealed to the students. Each feedback session lasted ~20 min and centered on the interpretation of self-collected data and building and testing a hypothesis. A comparison between the preliminary with the final mark, i.e., derived from the submitted final poster version, was considered as an assessment of achieved learning and yielded an ~20% increase in form of received points.

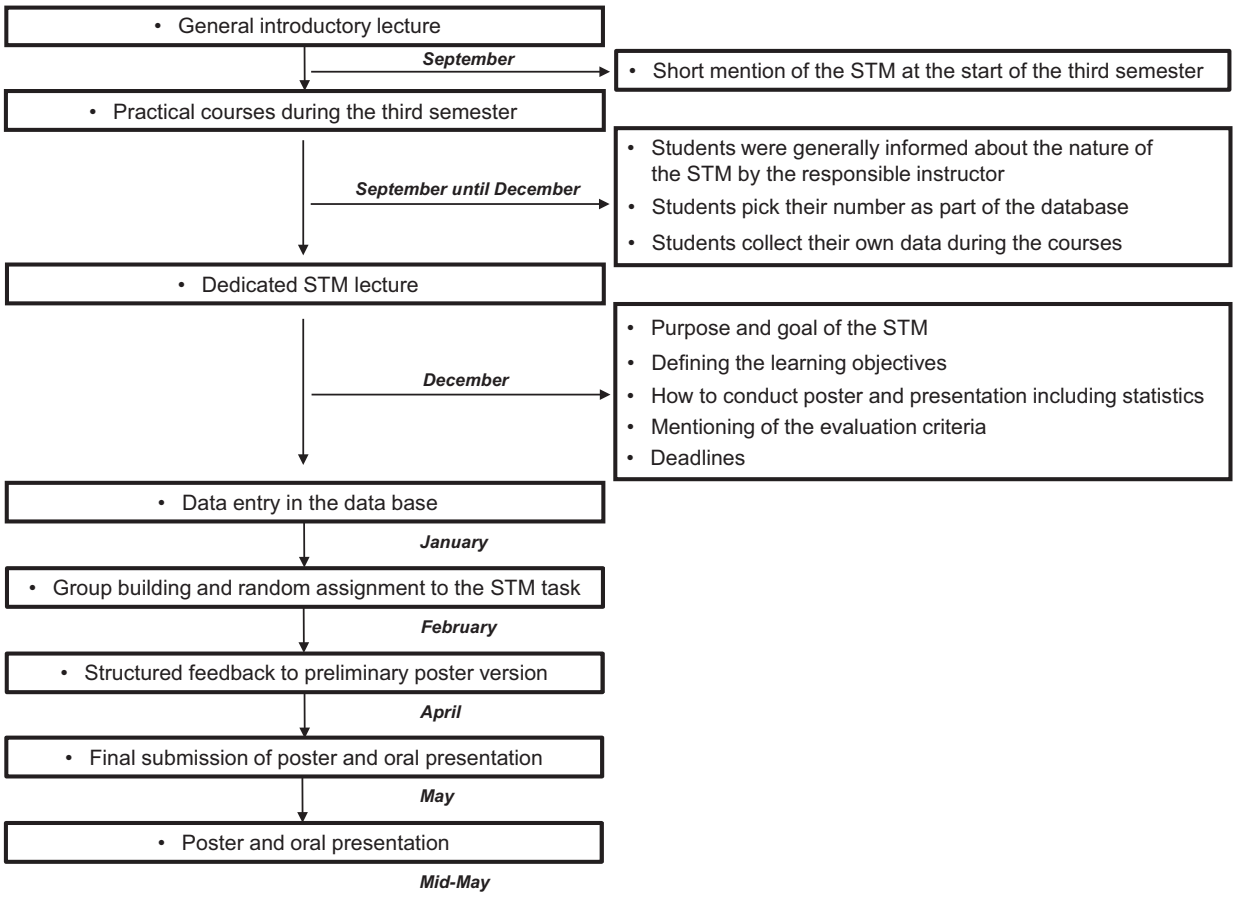

Fig. 2. Flow chart that depicts, in a time-dependent fashion (*top* down), pertinent constituent parts for a practical lecture course entitled, Scientific Thinking and Methodology (STM) (*left*). *Right*: a brief explanation and short summaries concerning working steps before entering data in the database.

Evaluation of the course. To avoid an evaluation bias toward a higher rating for the evaluation of our proposed teaching approach, we performed the evaluation before the students became aware of their final marks. Students evaluated our practical lecture course as follows (Likert-scale 1–7: 1 = total disagreement and 7 = total agreement): "The amount of work I put into the STM was adequate" [median: 5 points; mean: 4.5 ± 1.8 standard deviation (SD)]; "The STM helps me to build and a test a hypothesis and to solve a clinical problem" [median: 6 points; mean: 5.6 ± 1.2 (SD)]; "The STM helps me to reflect and critically interpret clinical data and medical literature" [median: 6 points; means: 5.5 ± 1.2 (SD)].

Table 1. *Selection of 10 study questions (translated from German or French) raised by medical students themselves that were based on self-collected data during physiology courses, which led to a refutable hypothesis*

	Study Questions
1.	Overweight and body mass index: Could it affect the electrical axis of the heart?
2.	Do taller people have a higher blood pressure?
3.	Is diastolic blood pressure related to anthropometric measurements?
4.	Does lifestyle affect blood pressure and heart rate values?
5.	Can the medical history of my parents affect my resting heart rate?
6.	Are heart rate changes during active standing related to body weight?
7.	Does urinary sodium excretion relate to resting blood pressure parameters?
8.	Does oral contraception intake relate to resting oxygen consumption?
9.	Do anthropometric parameters relate to lung vital capacity?
10.	Is there a relation between resting energy expenditure and body composition?

DISCUSSION

We present here a newly introduced and recently established scientific module for medical students, which allows students to *1*) collect and verify self-evaluated clinical data, and to *2*) build and test a refutable hypothesis with the aid of self-collected clinical data stored in an anonymous database. Additionally, the students gained access to a thorough assessment of clinical data and critical use for creating tables and figures, which comply with current scientific standards. Moreover, the students received an early opportunity to work in a team and present self-processed data in a mock scientific symposium.

In our highly connected world, newly generated information becomes available to readers within a fraction of a second, and, as such, lesser time is devoted to ensuring the information is scientifically accurate. Therefore, it is becoming increasingly difficult for medical doctors not only to keep abreast of scientific developments, but more importantly to separate the wheat from the chaff. Moreover, without a sound scientific background, on what basis will a medical doctor distinguish

between useful and misleading information? Simpkin and Schwartzstein (5) mentioned that, based on their experience, medical students are seeking structure, efficiency, and predictability and are disappointed when a "right answer" cannot be supplied, thereby potentially neglecting pertinent information from the patient, which would lay between these two strong poles. They suggested that, instead of speaking about a patient's diagnosis, students should rather focus and be taught to generate a hypothesis based on all of the patient's information (5). In such a scenario, the patient's diagnosis is expected to be in a dynamic and evolving state that resembles the falsification process common to hypothesis testing. However, the understanding of hypothesis generation and testing seems to be underdeveloped in medical students, even in their final year (1, 2). Indeed, when 25 final-year medical students were asked to write a sentence on "science", none mentioned the word "hypothesis" (1). When the evaluated students asked Professor Jeremy Hugh Baron about his own concept of science, he answered in five words: "Construct refutable hypothesis: test: publish" (1).

Therefore, we developed in our physiology curriculum a practical and economical way to teach the gathering and interpretation of clinical data where medical students tested a self-developed hypothesis with the aid of self-collected data from physiology laboratory courses. To facilitate the learning of the students, and aside from making analogical problems available, giving adequate feedback is deemed essential concerning the students' attempts at problem solving (3). Therefore, assigned instructors conducted a structured feedback session, using open-ended questions rather than directive statements, where particular emphasis was given to the treatment and the processing of data, which we consider as the foundation of hypothesis testing. When asking the students later in an anonymized evaluation about the usefulness of the feedback session to their learning, it yielded a mean score of 6.5 points out of 7 (median was 7).

Future directions and next iteration of our study concept. Although many medical schools have switched from specific physiology lectures to organ or system-oriented modules, our proposed teaching approach remains applicable as long as there are student laboratories with human data acquisition. We think that our concept of working on self-collected data and hypothesis testing is flexible and can be adapted to modules where the contributing instructors vary substantially between specialties. In such a scenario, each group of students could pick up their most favorable and interesting specialty concerning the practical teaching lessons where self-evaluated data were collected. Independent of the undergraduate curricula used (i.e., semester-long courses in physiology or organ system modules), we would like to emphasize the importance of a robust independent review, in particular for data collection (entry), its compilation, and access systems, to ensure highest quality standards.

In an attempt to provide a first-hand experience in basic scientific knowledge, we present a novel educational concept for undergraduate medical students in their earlier years of studies. Our goal was to educate students how to collect and treat all sorts of data derived from practical lectures during their physiology courses and to generate and test a clinically relevant hypothesis based on the initial data collected.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

E.K.G. and J.-P.M. conceived and designed research; E.K.G. performed experiments; E.K.G. analyzed data; E.K.G. and J.-P.M. interpreted results of experiments; E.K.G. prepared figures; E.K.G. drafted manuscript; E.K.G. and J.-P.M. edited and revised manuscript; E.K.G. and J.-P.M. approved final version of manuscript.

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