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INTEGRATING BIOSTATISTICS AND EXPERIMENTAL PHYSIOLOGY: STUDENTS' PERCEPTIONS AND FUTURE SCOPE

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Abstract : The use of biostatistics in experimental physiology is recognised by researchers. However, there has been no concerted attempt to integrate biostatistics into the undergraduate experimental physiology programme. This paper describes one such initiative. The student's response to the exercise was largely positive; it enabled them to describe and interpret data more effectively and understand the experiments more completely. The attitudes of the students to the exercise and their performance at a statistics examination at the end of the exercise was determined by a number of parameters, including prior statistical knowledge, general academic performance and the extent to which they liked mathematics. However, even those students who disliked mathematics indicated that they appreciated the value of the exercise. The results indicate the need to integrate biostatistics into the undergraduate physiology course.

Key words : medical education physiology statistics

INTRODUCTION

The interpretation of experimental and investigative data is one of the objectives of the physiology curriculum. In a wider context, the knowledge of statistics is important to medical graduates in situations where they perform research, keep abreast of current literature (1, 2) and undertake public health initiatives (3). Despite this, however, there has been no concerted effort to ensure that medical graduates in India are proficient in the application of biostatistics. Biostatistics and experimental physiology, inevitably go together. This provides a unique opportunity to integrate biostatistics into the experimental physiology course of undergraduates. This paper describes the attitudes of students to an integrated biostatistics programme that we recently introduced, outlines the determinants of their attitudes and explores the scope of such an integrated programme.

METHODS

Sixty students of the first term of I MBBS form the basis of this study. There were an equal number of males and females in the sample. At the time of the study the students had completed a set of practicals relating to nerve and muscle physiology using the gastrocnemius muscle and sciatic nerve preparation of the frog. The present exercise was carried out during a set of

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human experiments designed to record muscle strength and its determinants, and whole body and muscle endurance during exercise. Muscle strength was determined using a handgrip dynamometer (Harpenden, CMS Weighing Equipment Ltd. London). Anthropometric determinants of muscle strength assessed, included body size (from body mass index: weight in kg/height^2 in m), fat-free mass (from the BMI derived age and gender specific equation of Deurenberg) (4), muscle mass (5) and forearm muscle area (6). Isolated muscle endurance in the forearm was assessed using a handgrip dynamometer, coupled to a load cell and linked to a polygraph. Whole body fitness was assessed using a standard 2 km walking test (7).

The sequence that we followed is depicted in Table I. Prior to the statistical exercise, a pre-assessment form was given to the students. This form consisted of fixed-response questions (Yes/No), statements with which level of agreement was determined using a Likert-type scale, and open-ended questions. Students were also required to indicate from a standard list which statistical terms they had a working knowledge of. This list consisted of the following terms: mean, standard deviation, normal distribution, coefficient of variation, quartiles, centiles, correlation, P value, null hypothesis and 't' test. The form thus sought to determine the level of knowledge of statistics for each student, whether they received any prior formal training in statistics, and their attitudes towards statistics in terms of its benefits and disadvantages.

During the course of the experiments, students were provided with specific practical sheets which outlined the aims and procedures of the experiment. The worksheets incorporated tables and blank spaces into which students filled their data and calculated simple statistical parameters such as mean, standard deviation and coefficient of variation. The worksheets also contained the formulae for students to calculate derived anthropometric indices such as body mass index, fat-free mass, muscle mass and forearm muscle area. Students were instructed on the need to repeat measurements, as a means of determining measurement error and understanding the concept of intraindividual biological variability. After the experiment, the data sheets were collected from the students, entered on computer and analysed by a staff member.

TABLE I : Sequence of the present exercise.

1.	Administration of a pre-assessment questionnaire to determine prior attitudes and knowledge towards statistics (15 min)
2.	Physiology practical: collection of data
3.	Collation of data and statistical analysis on computer
4.	Theory class on biostatistics (60 min) with minimal mathematics
5.	Filling up of statistics worksheets for the physiology practical under faculty guidance (60 min)
6.	Administration of a post-assessment questionnaire
7.	Statistics test 1 week after 5, based on a subsequent practical (20 min)

Prior to the presentation of the results to students a single class was held covering very basic elements of descriptive and inferential statistics. Concepts that were covered included mean, standard deviation, range, centiles and quartiles, normal distribution, statistical significance and correlations. Care was taken to avoid the use of mathematical formulae, since this can be counter productive (8). The excessive use of statistical "jargon" was avoided and emphasis placed on the interpretation of data.

In order to facilitate the understanding of statistics as a descriptive and interpretative tool in experimental physiology, we prepared special statistical worksheets for the students. In the first worksheet, we reinforced some of the statistical concepts introduced in the lecture, by graphically depicting some of the statistical parameters (normal distribution, mean, SD, positive and negative correlations). The statistical worksheet was divided into a section on descriptive statistics and a section on inferential statistics. In the descriptive section students were required to compare their own data in relation to the data of the entire class. Statistical terms that were computed in this section included mean, SD, range and quartiles. In the inferential section students were required to note and then comment on data that had been subjected to correlations, and the 't' test. On the first occasion, the student's were instructed on how to fill these worksheets. A faculty member then presented the data sequentially to the entire class using an overhead projector, and the students filled these data into their worksheets. Interspersed in the worksheets were also questions which required students to interpret the data. The faculty member discussed each of these interpretative questions and guided the students on how to answer them.

After the first statistical exercise a post-assessment form was administered. This form included a table of statements which incorporated a Likert type scale (Table II). The standard list of statistical terms administered as part of the pre-assessment form was repeated as part of the post-assessment form in order to determine whether there was any increase in their working knowledge of statistics.

In order to assess whether the student's perceptions of their understanding of statistics determined from the post-assessment form, matched their actual performance, students were required to fill in a statistical worksheet on a subsequent practical, without any guidance. This constituted the "statistics test". Following the test, a worked out example of the test was put on the notice board so that all students could verify their answers. We have earlier demonstrated that such a "formative assessment" exercise with rapid feedback can be a powerful tool in facilitating learning (9).

The statistical analysis of the data was done depending on the nature of the data. For categorical data, non-parametric tests were applied; Wilcoxon test for paired data and the Mann Whitney test for independent data. For the remainder of the data parametric tests were used.

TABLE II : Distribution of student's perceptions of the statistics exercise, using a Likert-type scale.

	Not at all 1	*A little* 2	*Moderately* 3	*Quite a lot* 4	*Very much so* 5
To what extent has this exercise					
(a) Increased your knowledge of the use of statistics	–	2	15	29	11
(b) Been enjoyable	1	2	7	24	23
(c) Complicated things*	29	19	5	2	5
(d) Helped you to understand the experiment	–	1	13	20	23
(e) Helped you to describe the data	–	2	11	25	19
(f) Helped you to interpret the data**	–	1	15	22	18

The numbers indicate the number of reponses obtained. Three students were absent for this questionnare. *Two and one** student present for the questionnare did not fill up this response.

RESULTS

When asked to rate the subjects that they had done in school in terms of "likability", 43.3% (26/60) rated mathematics among the less likable subjects. Only 38% (22/60) of the students indicated that they had received formal training in statistics prior to this exercise. In keeping with this ~ 52% (31/60) rated their own knowledge of statistics as poor to very poor. The remainder indicated that their knowledge was adequate. No student rated their knowledge of statistics as being either good or excellent. When students were asked to tick those statistical terms that they had a working knowledge of from a standard list of 10 items (normal distribution, mean, standard deviation, coefficient of variation, centile, quartile, null hypothesis, correlation, P value, t test) ~ 87% (52/60) ticked 4 or less than 4 items. Despite this ~ 83% (50/60) felt that it was necessary for a doctor to have a working knowledge of statistics. 73% (44/60) of the students were aware of the importance of statistics in describing data, and a marginally smaller percentage (68%; 41/60) of the importance in interpreting data. 15% (9/60) felt that statistics complicated things.

Following the statistical exercise, the attitudes of the students were evaluated in terms of a questionnare with Likert-type scaling. This is represented in Table II. It is clear that a vast majority of students found the exercise enjoyable, and indicated that they had increased their knowledge. They also indicated that the exercise helped them to understand the experiment, describe and interpret data. Despite the fact that there were some students who continued to feel that statistics complicated things, an analysis of scores in the pre-assessment form revealed that the class as a whole found statistics less complicated after the present statistics exercise (Wilcoxon test; P=0.02). The number of statistical items that they felt familiar with, increased from before the exercise (pre; 2.3 ± 1.9 vs. Post; 7.6 ± 2.0 items, paired t-test, P < 0.01). 90% (54/60) of the students felt that such an exercise should be contiuned during their course and for future batches. Despite this very positive response, however, only 63% (38/60) felt that statistics should be integrated into the examinations. The primary reasons cited for not including it in examinations was the study load the students already had and that statistics was "difficult".

Since there was a wide scatter of attitudes, knowledge and performance during this exercise, we attempted to delineate the determinants of these variables. Students who listed their knowledge of statistics as poor before the exercise were less likely to appreciate the value of statistics in promoting understanding of experiments as compared to students who evaluated their knowledge as being adequate (3.9 ± 0.9 vs. 4.4 ± 0.7 on the Likert scale, P < 0.05). However, level of knowledge of statistics prior to the statistical exercise was not a determinant of performance in the statistics test. The 50^{th} percentile of marks achieved at the most recent physiology internal assessment examination was used to divide students into low academic performers and high academic performers. High academic performers derived greater benefits from the statistical exercise in terms of knowledge acquired (P< 0.01), and ability to interpret data (P < 0.02) than low academic performers. They also found the exercises more enjoyable (P=0.1), were able to describe data better (P=0.07), and were able to understand the experiments more (P=0.09), although these differences were not statistically different from the responses of low achievers. High academic achievers also performed better in the statistical test although again the difference was not significant. Students who listed mathematics among the most likable subjects performed better than students who indicated a relative dislike for mathematics (Table III). Prior exposure to statistics was not a determinant of performance in the statistics test or of attitudes.

TABLE III : Determinants of student performance in the statistics examination.

	Low performers	*High performers*	*P value*
Marks obtained in the statistics test (max=17)	7.4±2.5	14.5±2.3	0.000
No. of statistical terms familiar with, post-exercise (max = 10)	7.1±2.4	8.0±1.5	0.1
Degree of "positivity" about the exercise (a+b+d+e+f-c, from Table II)	18.1±3.9	19.0±3.4	0.39
Academic performance (internal assessment marks, max = 25)	15.7±3.0	16.8±2.1	0.13
"Likability" of mathematics (from 6 subjects at school, 1 = most likable	4.1±1.8	2.7±1.5	0.004

The marks obtained in the statistics test was positively correlated with the students own evaluation of their statistical knowledge, obtained from the number of choices they made out of the standard statistical item list ($r=0.38$, $P < 0.01$). Performance in the test, was also correlated with the extent of positivity that the students had about the entire exercise ($r=0.28$, $P < 0.05$). This was obtained as a composite figure from Table II (calculated as the sum of scores of a, b, d, e and f minus c). There was also a positive correlation between the students own evaluation of their statistical knowledge and their feelings of positivity towards the entire exercise ($r = 0.39$, $P < 0.01$). These analyses reflect the internal consistency of the data.

DISCUSSION

The importance of understanding statistics and applying it has been adequately recognised in the medical field. Medical education has moved away from providing information to developing critical thinkers, physicians who can integrate advances in science and medicine into the practice of medicine throughout their careers (10). The training of students to interpret data is in keeping with this overall objective. Traditionally, interpretation of data in student experiments in physiology has been largely qualitative. This paper demonstrates that collation of data and application of simple statistical methods as a routine part of the experimental physiology course can contribute towards an increased knowledge and the building up of positive attitudes towards statistics among medical students. In addition, the inferential scope of experiments is considerably enhanced. For instance, in the experiment of muscle strength, we were able to test various hypotheses; whether there were gender differences, whether muscle strength was related to muscle mass, and whether gender differences were explained by differences in muscle mass. These inferences were only possible through the application of statistics.

Our study demonstrates that there are a large number of students who dislike mathematics, and that this was a determinant of their performance in the statistics test. The level of academic performance is a determinant of attitudes, as is a prior knowledge of statistics. As a group, there were several encouraging outcomes of this exercise. Students indicated a significantly higher number of statistical terms that they had become familiar with, and results of the statistics test indicated that they were able to apply this new learning, to the extent of their acquired knowledge. Students also felt that statistics was less complicating than they initially thought. This may in part be because we refrained from making the exercise too mathematical; an approach that has been recommended for beginners (8). Students also indicated a high level of enjoyment, although this may, in part be because we applied the exercise to human experiments (11).

The integration of statistics into experimental physiology will only succeed if all Physiology teachers are familiar with the application of statistics. There is a possibility that without adequate preparation, this integration can evolve into a meaningless mathematical exercise which might actually prejudice students against learning and applying biostatics. A computer helps in the exercise that we have devised, because it allows for statistics to be generated in close proximity to the data collection. Statistical software in the public domain (EPIINFO for example) allows for the application of a wide range of statistical tests. Students can also be assigned the duty of data entry on rotation, and this will facilitate their understanding of applied computer skills.

The present paper demonstrates that it is possible to integrate effective statistical learning into an experimental physiology course. The vast opportunities during the physiology practical course allow students to apply their newly acquired statistics knowledge on data that they themselves have generated. This is likely to enhance their involvement in the learning process, and is distinct from traditional bio-statistics courses which are largely theoretical and use examples which may often be far removed from the interests of the student.

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