BMJ Open

Assessing statistical literacy in medical students and doctors: a survey in South Korea

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-095173
Article Type:	Original research
Date Submitted by the Author:	16-Oct-2024
Complete List of Authors:	Lee, Sun Young; Seoul National University Hospital, Public Healthcare Center; Seoul National University College of Medicine, Department of Human Systems Medicine Kim, Soela; Seoul National University Medical Research Center, Institute of Health Policy and Management Kim, Soyun; Seoul National University Medical Research Center, Institute of Health Policy and Management Shin, Yukyung; Seoul National University College of Medicine, Department of Health Policy and Management Yim, Jae-Joon; Seoul National University College of Medicine, Department of Internal Medicine; Seoul National University Hospital, Division of Pulmonary and Critical Medicine, Department of Internal Medicine Hwang, Hyeontaek; Seoul National University College of Medicine, Department of Internal Medicine; Seoul National University Bundang Hospital, Division of Pulmonary and Critical Medicine, Department of Internal Medicine Kwon, Youngsuk; Seoul National University Hospital Kim, Un-Na; Seoul National University College of Medicine, Department of Health Policy and Management; Korea Ministry of Health and Welfare Do, Young Kyung; Seoul National University College of Medicine, Department of Health Policy and Management; Seoul National University Medical Research Center, Institute of Health Policy and Management
Keywords:	MEDICAL EDUCATION & TRAINING, Health Literacy, STATISTICS & RESEARCH METHODS, Surveys and Questionnaires

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Title Page

Assessing statistical literacy in medical students and doctors: a survey in South Korea

Sun Young Lee[1,2], Soela Kim[3], Soyun Kim[3], Yukyung Shin[4], Jae-Joon Yim[5,6], Hyeontaek Hwang[5,7], Youngsuk Kwon[8], Un-Na Kim[4,9], Young Kyung Do[3,4,*]

[1]Public Healthcare Center, Seoul National University Hospital

[2]Department of Human Systems Medicine, Seoul National University College of Medicine

[3]Institute of Health Policy and Management, Seoul National University Medical Research Center

[4]Department of Health Policy and Management, Seoul National University College of Medicine

[5]Department of Internal Medicine, Seoul National University College of Medicine

[6]Division of Pulmonary and Critical Medicine, Department of Internal Medicine, Seoul National University Hospital

[7]Division of Pulmonary and Critical Medicine, Department of Internal Medicine, Seoul National University Bundang Hospital

[8]Seoul National University Hospital

[9]Ministry of Health and Welfare

*Corresponding author:

Young Kyung Do, M.D., M.P.H., Ph.D.

Department of Health Policy and Management

Seoul National University College of Medicine, South Korea.

Address: 103 Daehak-ro, Jongno-gu, Seoul 03080, Korea

E-mail: ykdo89@snu.ac.kr

Phone: +82-2-2072-3124

Fax: +82-2-743-2009

Assessing statistical literacy in medical students and doctors: a survey in South Korea

Abstract

Objective

Healthcare professionals must possess statistical literacy to provide evidence-based care and engage patients in decision-making. However, there have been concerns about healthcare professionals' inadequate understanding of health statistics. As an initial step in addressing the issue, we assessed the statistical literacy of medical students and doctors in South Korea by evaluating their comprehension of four statistical concepts: a) single-event probability, b) relative risk reduction, c) positive predictive value, and d) 5-year survival rate.

Design

Cross-sectional survey study

Setting

The survey was conducted from October 2018 to January 2019 in one medical school and one teaching hospital in Seoul, South Korea

Participants

303 medical students from one medical school and 291 doctors from one teaching hospital

Primary and secondary outcome measures

The primary outcome measure was the correct answer rate for each question. The secondary outcome measure was the mean number of correct answers across the four statistical literacy questions, calculated for each individual.

Results

The correct answer rates for basic numeracy questions were close to 100%. Regarding statistical literacy, 95.5% and 83.2% of the participants accurately understood single-event probability and relative risk reduction, respectively. However, only 49.3% and 49.2% of participants accurately understood the positive predictive value and 5-year survival rate, respectively. The correct answer rates for the question about the 5-year survival rate differed significantly between students (40.9%) and doctors (57.7%) (p <.001). There were no

statistically significant differences in the correct answer rates for other questions, regardless of the student's grade level or the doctor's specialty.

Conclusions

Medical students and doctors have weaker statistical literacy than their basic numeracy. Therefore, it is essential to implement medical education and professional development programs that focus on improving their statistical literacy. These programs should specifically address measures of medical test accuracy and the distinction between a 5-year survival rate and mortality.

Strengths and limitations of this study

- This study assessed the statistical literacy of Korean medical students at various academic levels and doctors with differing clinical experience and specialties for the first time, focusing on areas where statistical literacy may present significant challenges in clinical practice.
- A limitation of this study was that participants were recruited from only a single medical school and a teaching hospital in South Korea using a convenient sampling method.

Introduction

Statistical literacy in healthcare entails the ability to critically assess statistics in health information and understand statistical concepts in healthcare(1, 2). This competency is essential for healthcare professionals practicing evidence-based medicine, where medical decisions are guided by the best available evidence—often numerically represented—alongside clinical expertise and patients' values and preferences (3, 4) For healthcare professionals, statistical literacy serves several critical functions. First, it enables the analysis and interpretation of emerging quantitative evidence about the benefits and risks of various healthcare options. Second, it allows for accurate statistical inferences from test results, aiding in accurate diagnosis and effective treatment planning.(4, 5) Third, it facilitates clear explanations of the implications of tests and treatments to patients, supporting informed, shared decision-making.(6) Without statistical literacy, healthcare professionals may struggle to provide optimal care and effectively involve patients in their healthcare decisions.

Despite the critical importance of statistical literacy in healthcare, numerous studies have identified common misunderstandings and errors among health professionals about statistical concepts.(5, 7) For example, healthcare professionals often struggle to comprehend and explain statistical concepts such as single-event probability (e.g., there is a 10% chance of an allergic reaction to a medication) and relative risk reduction (RRR, e.g., a new drug reduces the risk of having a heart attack by 60% when compared to a placebo).(2, 5, 7, 8) Moreover, medical students and doctors frequently find it challenging to understand conditional probabilities like sensitivity and specificity, and how to combine them with disease prevalence to estimate the positive predictive value (PPV: the conditional probability of having a disease when a test result is positive) (5, 9-18) Errors in estimating PPV can lead to severe consequences. Overestimating PPV can lead to overdiagnosis and overtreatment, causing unnecessary anxiety, costs, and harm to patients.(5, 16-19). Conversely, underestimating PPV can result in missed opportunities for early intervention and worsen patient outcomes. Additionally, healthcare professionals often conflate an increase in the 5-

year survival rate with a reduction in mortality, even though these statistics measure different aspects of clinical and epidemiological data.(13, 20) The 5-year survival rate represents the proportion of individuals who survive five years after being diagnosed with an illness, whereas mortality refers to the annual rate of disease-related deaths within a given population. Screening asymptomatic individuals can increase the 5-year survival rate by detecting the disease earlier, but it may not reduce mortality if the disease progression or treatment outcomes are unaffected. Therefore, relying solely on a 5-year survival rate, or confusing it with mortality, can misrepresent the life-saving benefits of screening programs.(8, 13, 20, 21) As evidenced in these widespread misunderstandings of fundamental statistical concepts, the lack of statistical health literacy among healthcare professionals not only impedes accurate assessment of medical interventions but also potentially compromises the overall effectiveness of evidence-based medicine. (1, 5, 20, 22)

Although statistical literacy, like other medical knowledge and clinical skills, can affect patient health outcomes, the medical education community often overlooks the importance of continuously enhancing formal training to foster statistical literacy. To introduce improved formal training to medical students and doctors, it is imperative to assess their current statistical literacy on major clinical issues highlighted in the literature and identify areas for improvement. For a notable example, a study from Germany assessed the minimum statistical literacy of 169 final-year medical students, measuring their understanding of 10 basic statistics concepts, including sensitivity, specificity, PPV, RRR, and mortality.(2) The students' median percentage of correct answers to these questions was 50% before brief training, which increased to 90% afterward.

We aimed to assess the statistical literacy of medical students and doctors in South Korea, combining the conceptual components of the German study and adapting them to a more clinically relevant context.(2) When assessing statistical literacy, we focused on understanding four key statistical concepts: a) single-event probability, b) RRR, c) PPV, and d) 5-year survival rate. We also assessed their basic numeracy (i.e., an elementary skill to

understand and use numbers), which may be a prerequisite for statistical literacy.(5) This assessment will help identify which statistical concepts are most challenging for our target population and guide the development of improved medical education.

Methods

Study setting

Between October 2018 and January 2019, we conducted a cross-sectional survey among a convenience sample of medical students enrolled at one medical school and doctors at one teaching hospital in Seoul, South Korea. Medical students from all six years of the program, trainee doctors (interns and residents), and attending physicians at the hospital were eligible to participate in the study. We contacted student organizations and resident physicians to inform them about the study and sought their assistance in recruiting participants. Co-investigators, who were medical students or doctors-in-training themselves, approached potential participants before and after events, such as meetings, classes, and conferences that many students and doctors attended. They explained the study and invited individuals to participate. Participants who agreed were given a questionnaire on the spot. The entire questionnaire included two separate thematic sections: medical statistical literacy (the focus of this paper) and patient-centeredness (not reported in this paper) along with key demographic information, such as gender, age, students' year of study or doctor's grade and specialty. The questionnaire took approximately 5–10 minutes to complete. Participants received a gift card worth around 4 USD as a token of appreciation. This study was approved by the Institutional Review Board of Seoul National University (IRB No. 1808-185-969).

Sample

Our use of convenience sampling from a single medical school and teaching hospital may limit the generalizability of our findings. To mitigate this, we aimed for a diverse sample across different years of study for students and different specialties for doctors. For medical students, our goal was to survey approximately one-third of students in each grade of the six-

year medical school program, targeting 50 students per year for a total student sample of 300. Due to the expected challenges in surveying hospital doctors, we targeted approximately one-fourth of the trainee doctors, including both one-year interns and three- or four-year residents, as well as 100 attending physicians from a total of nearly 900. Since interns are not yet affiliated with a specialty, specialty information was collected only from residents and attending physicians. We aimed to survey residents and attending physicians from 13 specialties out of the 23 clinical specialties, which we classified into three main groups: medical (internal medicine, pediatrics, rehabilitation, family medicine, and psychiatry), surgical (emergency medicine, obstetrics and gynecology, orthopedics, otorhinolaryngology, and general surgery), and service (radiology, laboratory medicine, and anesthesiology). The approximate proportion of these groups in our sample was set to 5:3:2 for residents and attending physicians, reflecting the proportion of residency openings in these specialties in 2019. See Supplementary Table 1 for target and actual numbers of participants.

Measures

To assess basic numeracy, we used three fill-in-the-blank questions previously designed to evaluate numeracy skills among medical students and doctors.(5) These questions involved converting between percentages and frequencies and interpreting chance outcomes. We then developed four questions to assess medical statistical literacy, drawing from two previous studies.(2, 5) While these questions were based on the concepts presented in the previous studies, we incorporated our own experience in clinical medicine and medical education to ensure they addressed statistical concepts frequently discussed in real-world clinical situations and patient consultations. These questions evaluated participants' comprehension of single-event probability, RRR, PPV, and 5-year survival rate. The question on single-event probability was included as it is often confusing due to the lack of a reference class, causing diverse misunderstandings. The RRR question aimed to assess participants' ability to explain this concept in the context of comparing new versus conventional chemotherapy. The PPV question involved calculating the probability of having breast cancer given a positive

mammogram result, using information on sensitivity, specificity, and prevalence. The question on the 5-year survival rate was framed around the increased survival rates of thyroid cancer in South Korea to evaluate participants' understanding of the distinction between increased survival and reduced mortality.(5, 21) See Box 1 for an English translation of the exact wording of the questions and response options.

[Insert Box 1 about here]

Statistical analysis

The percentage of correct answers for each basic numeracy and statistical literacy question was computed. We analyzed the percentage of correct answers for medical students and doctors for the four statistical literacy questions, examining variations by students' grades and doctors' specialty. Differences between subgroups were compared using the chi-square test for two groups and ANOVA for three groups. All statistical analyses were conducted using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). *P*-values were based on a two-sided significance level of 0.05.

Patient and public involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study.

Results

A total of 303 medical students and 291 doctors participated in the survey. Table 1 presents the characteristics of the participants.

[Insert Table 1 about here]

The correct answer rate for all three basic numeracy questions was close to 100% in both the student and doctor groups (Figure 1). The first two statistical literacy questions—the single-event probability question and the RRR question—also had high correct answer rates, approximately 95% and 83%, respectively. However, the PPV question and the 5-year survival rate question had much lower correct answer rates, approximately 49%. There was no notable difference in correct answer rates between medical students and doctors, except

for the 5-year survival rate question, where doctors had a higher correct answer rate (57.7%) than medical students (40.9%, $p < 0.001$). See Supplementary Table 2 for the distributions of answer choices selected for each statistical literacy question.

[Insert Figure 1 about here]

Figure 2 presents the percentage of correct answers given by medical students at different grade levels for statistical literacy questions. In general, the correct answer rate increased with grade level, although the observed differences were not statistically significant. For instance, 46.6% of the third- and fourth-year medical students answered the 5-year survival rate question correctly, compared to 38.0% of the premedical and first- and second-year medical students.

[Insert Figure 2 about here]

Doctors in service specialties consistently demonstrated higher correct answer rates than those in medical or surgical specialties, although these differences were not statistically significant (Figure 3). Notably, the correct answer rate for the PPV question was higher among doctors in service specialties (56.1%) compared to their peers in medical (48.8%) and surgical (47.6%) specialties. The overall mean score on the four statistical literacy questions was also slightly higher among doctors in service specialties (Supplementary Table 3).

[Insert Figure 3 about here]

Discussion

Despite their high basic numeracy, the medical students and doctors in this study demonstrated areas for improvement in key aspects of statistical literacy. While over 80% of participants correctly answered questions on single-event probability and RRR, correct answer rates were substantially lower for the PPV and 5-year survival rate questions. Both groups performed similarly on most questions, except for the 5-year survival question, where medical students had a significantly lower correct answer rate than doctors. Notably, increasing years in medical school did not result in considerably higher correct answer rates.

While this study may offer only a snapshot of the statistical literacy of Korean medical students and doctors, it serves as a window to examine the current state of medical education concerning statistical literacy in South Korea and beyond. Since the students and doctors in this study possessed high basic numeracy skills, their underdeveloped statistical literacy cannot be attributed to their basic numeracy. The two questions about statistical literacy, single-event probability and RRR, had high correct answer rates. This could be mainly because they are more closely related to basic numeracy compared to the other two questions, PPV and 5-year survival rate. These are areas where medical education can play an important role. Previous studies have linked insufficient statistical literacy in doctors to a non-transparent presentation of statistical information and to medical schools that do not give adequate attention to the importance of teaching risk communication.(2, 5) Therefore, it is crucial to introduce medical education and professional development programs that enhance statistical literacy among medical students and doctors. In these programs, the main focus should be on enhancing the ability to make statistical inferences from medical test results and to acquire proficiency in using relevant medical statistics to critically evaluate the effects of illness and the life-saving advantages of medical treatments. The following discussion focuses on the two areas—PPV and 5-year survival rate, where there is a large room for improvement, as demonstrated in this study.

Although the medical students and doctors in this study had a significantly higher accuracy rate (approximately 49%) in answering the PPV question compared to their counterparts in previous German studies (approximately 20%)(2, 5), this rate is still far from satisfactory, particularly from a medical education standpoint. Our results indicated that being in higher years in medical school and even currently practicing medicine as a doctor was not associated with higher correct answer rates for the PPV question, suggesting both undergraduate and postgraduate medical education could improve significantly. Participants might have confused the PPV with sensitivity,(11) which was presented as 90% in the question. Alternatively, the tendency to overestimate PPVs, as observed in previous studies,

(10, 14, 23, 24) might have led to the incorrect answer. Regardless of which explanation is more plausible, it is important to remember that overestimating PPVs of medical tests can lead to further tests, unnecessary treatments, and potential patient harm.(5) There is ample evidence that presenting statistical information in the form of natural frequencies rather than probabilities can improve conditional probabilistic reasoning, as it helps with an intuitive understanding of conditional probabilities(15, 25-28). The observed effect of the natural frequency format was evident in individuals with both high and low numeracy.(26, 29) Furthermore, studies have shown that teaching medical students and doctors how to translate relevant statistical information presented in probabilities into natural frequencies also facilitates conditional probabilistic reasoning.(5, 25, 30, 31) It would be helpful to incorporate these research findings more actively when developing training programs to improve medical students' and doctors' ability to estimate the predictive values of medical tests.

Another major weak area in statistical literacy identified in this study was the confusion between 5-year survival rate and mortality. Almost half of medical students and one-third of doctors in this study incorrectly believed that an increase in the 5-year survival rate of thyroid cancer indicates a decrease in mortality from the disease. The relatively higher correct answer rate among doctors compared to medical students is likely due to their experience in clinical practice, where the concepts of 5-year survival rates and mortality are frequently used and compared. Nevertheless, the correct answer rate was still less than 60% among doctors and even lower among medical students, which is concerning because these two concepts must be carefully distinguished when assessing the impact of illness and the life-saving benefits of medical interventions.(5, 21) Otherwise, healthcare professionals may overestimate the life-saving advantages of cancer screening, which could explain the overutilization of low-value cancer screenings and the overdiagnosis of cancer. This misunderstanding has far-reaching consequences. Indeed, the overuse of low-value cancer screenings is contributing to cancer overdiagnosis and overtreatment globally, with South

Korea being a particularly notable example of this trend.(32-34) When teaching about the 5-year survival rate and mortality, it is critical to emphasize their key difference: the denominators used in their calculation. For 5-year survival rate, the denominator is the number of people diagnosed with the disease, whereas for mortality rate, it is the number of people in the general population.(21, 35) Understanding this distinction is essential for correctly interpreting these statistics in medical contexts. Utilizing visual aids such as bar charts or pie charts can be helpful. These graphics could separately show (i) the proportion of people who survived for five years after being diagnosed with a certain disease (5-year survival rate), and (ii) the annual rate of disease-related deaths in the population (mortality rate). Such visual representations can also facilitate comparing these rates across different populations or groups.(19)

This study has several limitations. First, we recruited participants from only a single medical school and a teaching hospital in South Korea using a convenient sampling method. This approach may have introduced selection bias, potentially limiting the generalizability of our findings beyond the specific institutions involved to the broader population of medical students and doctors across South Korea. Additionally, participants who chose to respond to our survey might have different statistical literacy characteristics than those who didn't participate. This could lead to overestimating statistical literacy if those who felt more confident in their abilities were more likely to participate. Second, while our work focused on key weak areas of statistical literacy among medical students and doctors as highlighted in previous research (2, 5), it must be explicitly acknowledged that the questionnaire does not comprehensively cover all aspects of statistical literacy relevant to medical practice, as one would expect from a validated instrument. Third, we did not investigate factors that may influence statistical literacy beyond examining its associations with basic characteristics available in the data.

Despite these limitations, this study provides the first assessment of the statistical literacy of Korean medical students in varying grades and doctors with varying clinical

experience and specialties. Based on the findings of this study, we designed and carried out an educational intervention aimed at improving medical students' statistical literacy, that is necessary to understand medical statistics and critically assess the available scientific evidence. We believe that this study will inspire further research in improving medical education regarding statistical literacy in South Korea and other countries.

Acknowledgments: We thank the medical students and doctors who voluntarily participated in this study.

Funding: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2018R1A2B2009257). The funder was not involved in the design of the study, the collection, analysis, and interpretation of data, or in writing the submitted work.

Conflict of interest: The authors have declared that no competing interests exist.

Ethical approval: This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1808-185-969) and informed consent was obtained from the participants.

Authors' contribution

SYL, UNK, and YKD developed the questionnaire. SYL, YS, JJY, HH, YK, and YKD contributed to data collection. SYL conducted the statistical analysis and wrote the first draft of the manuscript. SYL, Soela K, Soyun K, and YKD critically reviewed and revised earlier drafts. All authors reviewed and provided input during the revision process. YKD secured funding for this study.

Data sharing statement

The datasets used in the current study are available from the corresponding author upon reasonable request.

Box 1. Questionnaire to assess basic numeracy and medical statistical literacy

Basic Numeracy

BN Q1. People who take drug A have a 1% chance of having an allergic reaction. If 1000 people take drug A, how many people are expected to have an allergic reaction?
Answer: _____ out of 1000 (*Correct answer: 10*)

BN Q2. 1 out of 1000 people who take drug B may have an allergic reaction. What percentage of people who take drug B are expected to have an allergic reaction?
Answer: _____ % (*Correct answer: 0.1*)

BN Q3. Suppose that a coin is tossed 1000 times. How many times do you expect to get heads out of 1000 attempts?
Answer: About _____ times out of 1000 (*Correct answer: 500*)

Statistical Literacy

SL Q1. Antidepressant C has a 20% risk of causing weight gain. Which of the following is the most correct explanation? (*Single-event probability*)
a. Patients with depression who take C have a 20% increase in weight.
b. 2 out of 10 patients with depression who take C experience weight gain. ***
c. If you take 10 pills of C, 2 of them have a risk of causing weight gain.
d. If you take C for 10 months, you are at risk of weight gain for 2 months.

SL Q2. A new chemotherapy drug reduces the risk of vomiting (as a side effect) by 60% compared to conventional chemotherapy. Which of the following is the most correct explanation? (*Relative risk reduction*)
a. When using the new chemotherapy, the risk of vomiting is reduced to 40%.
b. When using the new chemotherapy, vomiting occurs in 40 of 100 patients.
c. Among 100 patients, the number of patients experiencing vomiting is reduced by 60 when using the new chemotherapy compared to conventional chemotherapy.
d. If vomiting occurs in 50 out of 100 patients when using conventional chemotherapy, vomiting occurs in 20 out of 100 patients when using the new chemotherapy. ***

SL Q3. The prevalence of breast cancer for women in their 60s is 1%. A woman with breast cancer has a 90% chance of being positive on a mammogram, and a woman without breast cancer has a 9% chance of testing positive on a mammogram. Which of the following is the closest to the probability that a woman with a positive mammogram actually has breast cancer? (*Positive predictive value*)
a. 81%
b. 9 out of 10
c. 1 out of 10 ***
d. 1%

SL Q4. The 5-year survival rate of thyroid cancer in South Korea has improved compared to the past. Which of the following is the most correct explanation? (*5-year survival rate*)
a. It is possible that the incidence of thyroid cancer has decreased.
b. An improvement in the 5-year survival rate of thyroid cancer means an improvement in the cure rate of thyroid cancer.
c. An improvement in the 5-year survival rate of thyroid cancer means a reduction in mortality due to thyroid cancer.
d. Early detection of thyroid cancer may increase the 5-year survival rate, but may not reduce mortality. ***

Notes. *** denotes the correct answer. The questionnaire was administered in Korean; this is an English translation. Italicized words were not included in the questionnaire but are shown here for clarity.

17

Table 1. Characteristics of study participants

		Total (N=594)		Medical Students (n=303)		Doctors (n=291)	
		n	%	n	%	n	%
Age group							
	–19	37	6.2	37	12.2	0	0.0
	20–29	371	62.5	265	87.5	106	36.4
	30–39	140	23.6	1	0.3	139	47.8
	40–49	44	7.4	0	0.0	44	15.1
	50+	2	0.3	0	0.0	2	0.7
Gender							
	Male	355	59.8	179	59.1	176	60.5
	Female	239	40.2	124	40.9	115	39.5
Student's grade							
	Premedical			100	33.0		
	Medical			203	67.0		
Doctor's grade							
	Intern					40	13.7
	Resident					146	50.2
	Attending					105	36.1
Doctor's specialty							
	Medical					125	43.0
	Surgical					84	28.9
	Service					41	14.1
	Missing					1	0.3

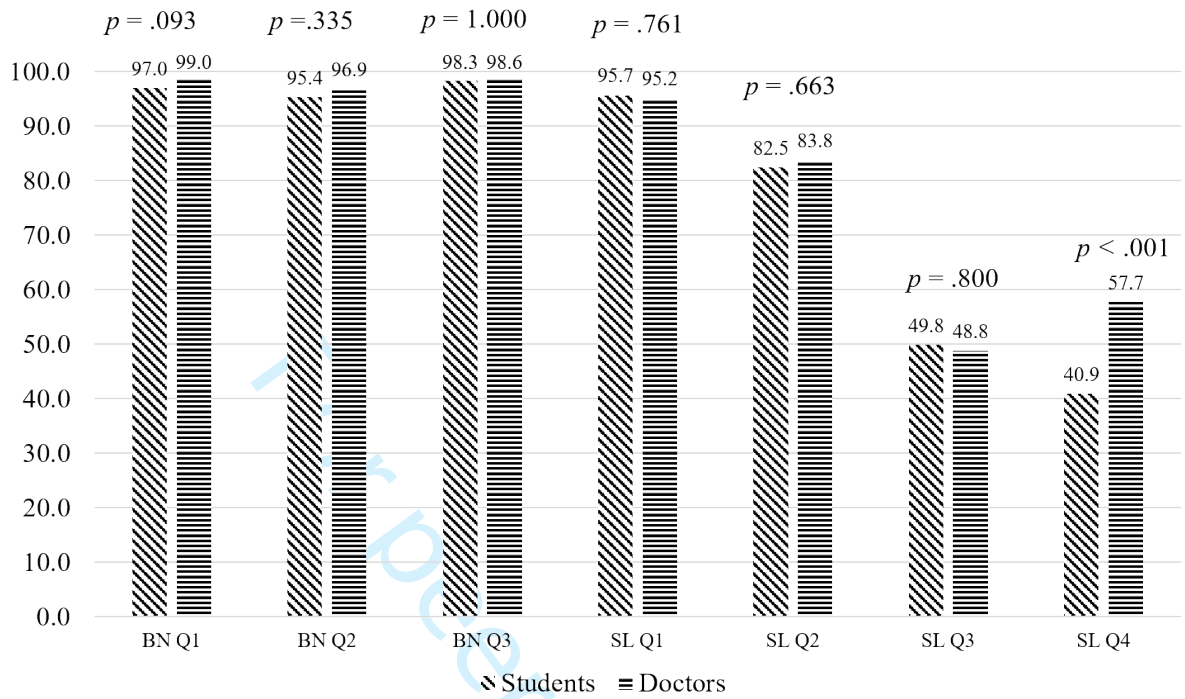
Note. See the text for the classification of medical specialties.

References

1. Gigerenzer G, Gray JAM. Launching the Century of the Patient. In: Gigerenzer G, Gray JAM, editors. Better Doctors, Better Patients, Better Decisions. Envisioning Health Care 2020: The MIT Press; 2011. p. 3-28.
2. Jenny MA, Keller N, Gigerenzer G. Assessing minimal medical statistical literacy using the Quick Risk Test: a prospective observational study in Germany. BMJ open. 2018;8(8):e020847.
3. Monahan J. Statistical literacy: A prerequisite for evidence-based medicine. SAGE Publications Sage CA: Los Angeles, CA; 2007. p. i-ii.
4. Schmidt FM, Zottmann JM, Sailer M, Fischer MR, Berndt M. Statistical literacy and scientific reasoning & argumentation in physicians. GMS Journal for Medical Education. 2021;38(4).
5. Gigerenzer G, Gaissmaier W, Kurz-Milcke E, Schwartz LM, Woloshin S. Helping doctors and patients make sense of health statistics. Psychological science in the public interest. 2007;8(2):53-96.
6. Osborn CY. Shared decision making requires statistical literacy. AMA Journal of Ethics. 2009;11(4):301-5.
7. Gigerenzer G. Better doctors, better patients, better decisions. 2014.
8. Gigerenzer G. Making sense of health statistics. Bull World Health Organ. 2009;87(8):567.
9. Bramwell R, West H, Salmon P. Health professionals' and service users' interpretation of screening test results: experimental study. BMJ. 2006;333(7562):284.
10. Casscells W, Schoenberger A, Graboys TB. Interpretation by Physicians of Clinical Laboratory Results. New Engl J Med. 1978;299(18):999-1001.
11. Eddy DM. Probabilistic reasoning in clinical medicine: Problems and opportunities. In: Kahneman D, Slovic P, Tversky A, editors. Judgment under uncertainty: Heuristics and biases Cambridge: Cambridge University Press; 1982. p. 249-67.
12. Wegwarth O, Gigerenzer G. US gynecologists' estimates and beliefs regarding ovarian cancer screening's effectiveness 5 years after release of the PLCO evidence. Scientific reports. 2018;8(1):17181.
13. Wegwarth O, Schwartz LM, Woloshin S, Gaissmaier W, Gigerenzer G. Do physicians understand cancer screening statistics? A national survey of primary care physicians in the United States. Annals of internal medicine. 2012;156(5):340-9.
14. Whiting PF, Davenport C, Jameson C, Burke M, Sterne JA, Hyde C, et al. How well do health professionals interpret diagnostic information? A systematic review. BMJ Open. 2015;5(7):e008155.
15. Hoffrage U, Gigerenzer G. Using natural frequencies to improve diagnostic inferences. Acad Med. 1998;73(5):538-40.
16. Aronowitz R, Greene JA. Contingent knowledge and looping effects—a 66-year-old man with PSA-detected prostate cancer and regrets. New Engl J Med. 2019.
17. Gigerenzer G. HIV screening: helping clinicians make sense of test results to patients. BMJ. 2013;347:f5151.
18. Gigerenzer G, Hoffrage U, Ebert A. AIDS counselling for low-risk clients. AIDS care. 1998;10(2):197-211.
19. Fagerlin A, Zikmund-Fisher BJ, Ubel PA. Helping Patients Decide: Ten Steps to Better Risk Communication. JNCI: Journal of the National Cancer Institute. 2011;103(19):1436-43.
20. Wegwarth O, Gaissmaier W, Gigerenzer G. Deceiving numbers: survival rates and their impact on doctors' risk communication. Med Decis Making. 2011;31(3):386-94.
21. Welch HG, Schwartz LM, Woloshin S. Are increasing 5-year survival rates evidence of success against cancer? Jama. 2000;283(22):2975-8.
22. Petrova D, Mas G, Navarrete G, Rodriguez TT, Ortiz PJ, Garcia-Retamero R. Cancer screening risk literacy of physicians in training: An experimental study. PLOS ONE.

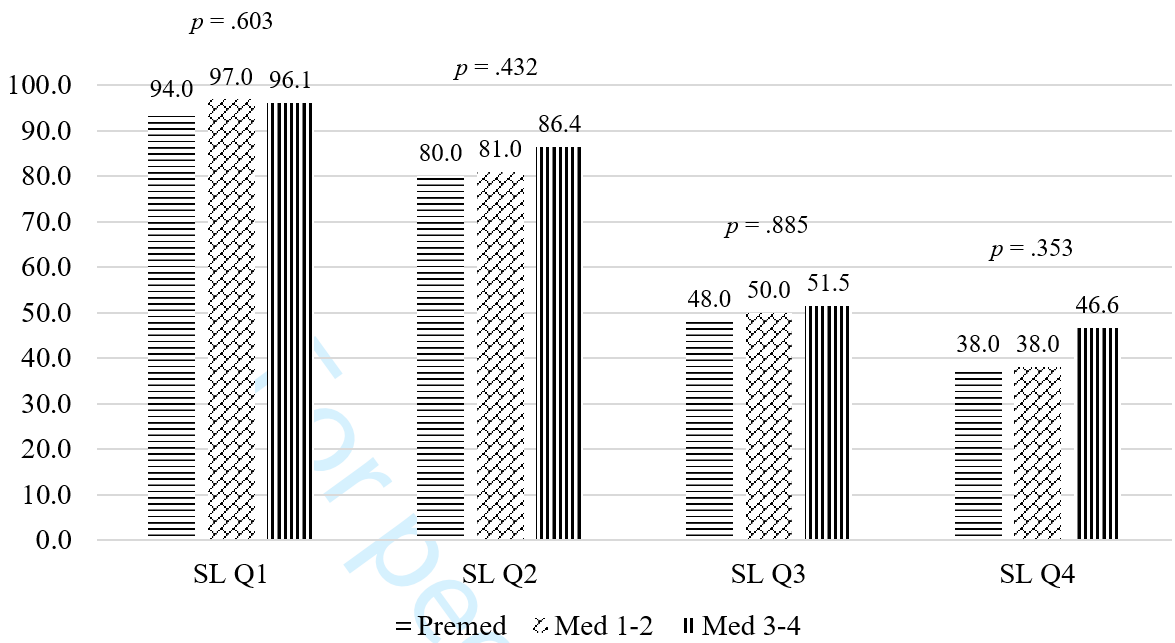
2019;14(7):e0218821.
23. Manrai AK, Bhatia G, Strymish J, Kohane IS, Jain SH. Medicine's uncomfortable relationship with math: calculating positive predictive value. JAMA Intern Med. 2014;174(6):991-3.
24. Lyman GH, Balducci L. Overestimation of test effects in clinical judgment. J Cancer Educ. 1993;8(4):297-307.
25. Feufel MA, Keller N, Kendel F, Spies CD. Boosting for insight and/or boosting for agency? How to maximize accurate test interpretation with natural frequencies. BMC Medical Education. 2023;23(1):75.
26. Galesic M, Gigerenzer G, Straubinger N. Natural frequencies help older adults and people with low numeracy to evaluate medical screening tests. Medical Decision Making. 2009;29(3):368-71.
27. Gigerenzer G. What are natural frequencies? Bmj. 2011;343:d6386.
28. McDowell M, Jacobs P. Meta-analysis of the effect of natural frequencies on Bayesian reasoning. Psychological bulletin. 2017;143(12):1273.
29. Chapman GB, Liu J. Numeracy, frequency, and Bayesian reasoning. Judgment and Decision Making. 2009;4(1):34-40.
30. Sedlmeier P, Gigerenzer G. Teaching Bayesian reasoning in less than two hours. J Exp Psychol Gen. 2001;130(3):380-400.
31. Kurzenhäuser S, Hoffrage U. Teaching Bayesian reasoning: an evaluation of a classroom tutorial for medical students. Med Teach. 2002;24(5):516-21.
32. Li M, Dal Maso L, Vaccarella S. Global trends in thyroid cancer incidence and the impact of overdiagnosis. The Lancet Diabetes & Endocrinology. 2020;8(6):468-70.
33. Ahn HS, Kim HJ, Welch HG. Korea's thyroid-cancer "epidemic"—screening and overdiagnosis. New Engl J Med. 2014;371(19):1765-7.
34. Lee J-H, Shin SW. Overdiagnosis and screening for thyroid cancer in Korea. The Lancet. 2014;384(9957):1848.
35. Gigerenzer G, Wegwarth O. Five year survival rates can mislead. BMJ: British Medical Journal (Online). 2013;346.

Figure 1. Correct answer rates for basic numeracy and medical statistical literacy questions



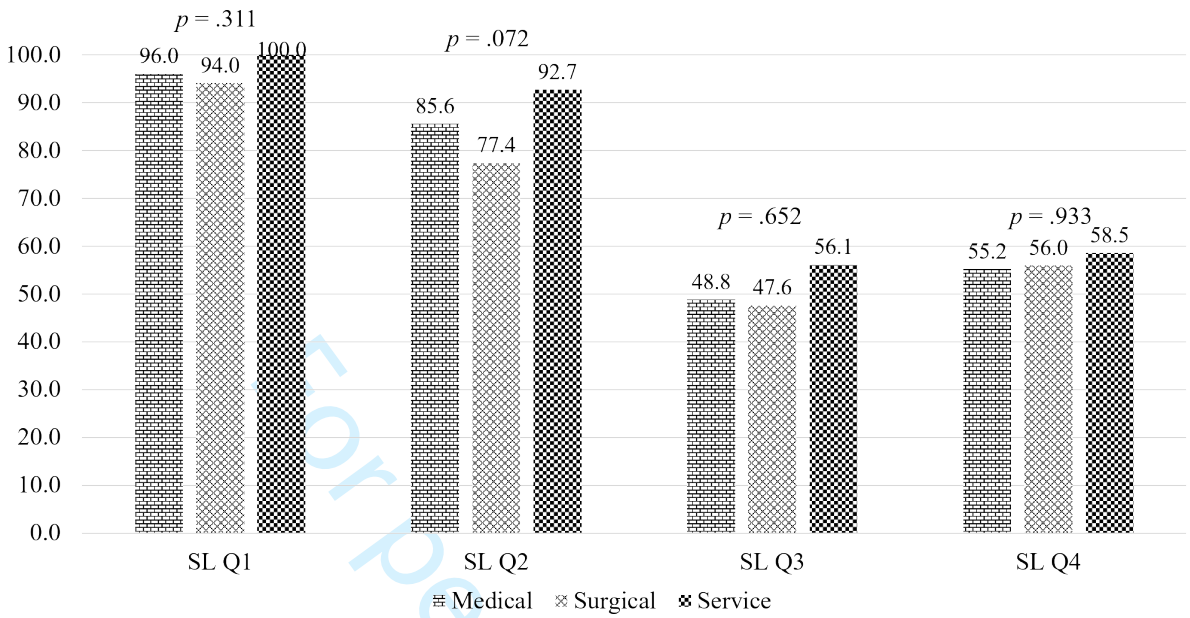
Notes. BN Q1: Converting a percent to a proportion, BN Q2: Converting a proportion to a percent, BN Q3: Familiarity with chance outcome, SL Q1: Single-event probability, SL Q2: Relative risk reduction, SL Q3: Positive predictive value, SL Q4: 5-year survival rate.

Figure 2. Correct answer rates for medical statistical literacy questions by student grade



Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate.

Figure 3. Correct answer rates for medical statistical literacy questions by specialty



Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate. See the text for the classification of medical specialties. Interns are not included in this analysis. The response from one attending physician who did not specify specialty was excluded from the analysis.

Assessing statistical literacy in medical students and doctors: a survey in South Korea

Supplementary Table 1. Target and actual numbers of participants

			Target number of participants	Actual number of participants	% of goal
Student	Premedical	1st year	50	50	100.0
		2nd year	50	50	100.0
	Medical	1st year	50	50	100.0
		2nd year	50	50	100.0
		3rd year	50	53	106.0
		4th year	50	50	100.0
	Total		300	303	101.0
Doctor	Intern	—	40	40	100.0
	Resident	Medical	68	68	100.0
		Surgical	40	51	127.5
		Service	24	26	108.3
	Attending	Medical	62	57	91.9
		Surgical	30	33	110.0
		Service	16	15	93.8
		Missing	—	1	—
	Total		280	291	103.9
Total			580	594	102.4

Note. See the text for the classification of medical specialties.

Supplementary Table 2. Distribution of answer choices selected to medical statistical literacy questions by medical students and doctors (%)

Choice	Single-event probability		Relative risk reduction		Positive predictive value		5-year survival rate	
	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)
1	1.7	2.1	5.0	4.8	11.6	15.8	1.7	0.3
2	**95.7**	**95.2**	0.3	0.0	24.8	25.1	8.3	9.6
3	2.3	2.7	12.2	11.3	**49.8**	**48.8**	49.2	32.3
4	0.3	0.0	**82.5**	**83.8**	13.5	10.0	**40.9**	**57.7**
Missing					0.3			

Notes: The correct answers are in bold.

Supplementary Table 3. Mean scores of medical statistical literacy by characteristics of study participants

		Total (N=594)			Medical Students (n=303)			Doctors (n=291)		
		n	Mean	*SD*	n	Mean	*SD*	n	Mean	*SD*
Total			2.8	0.9		2.7	0.9		2.9	1.0
Age group										
	–19	37	2.4	0.9	37	2.4	0.9			
	20–29	371	2.8	0.9	265	2.7	0.9	106	3.1	1.0
	30–39	140	2.6	0.9	1	4.0	—	139	2.6	0.9
	40–49	44	3.1	0.9				44	3.1	0.9
	50+	2	3.0	1.4				2	3.0	1.4
Gender										
	Male	355	2.9	0.9	179	2.8	0.9	176	3.0	1.0
	Female	239	2.6	0.9	124	2.5	0.9	115	2.7	0.9
Student's grade										
	Premedical				100	2.6	0.9			
	Medical				203	2.7	0.9			
Doctor's grade										
	Intern							40	2.8	1.2
	Resident							146	2.8	1.0
	Attending							105	3.0	0.8
Doctor's specialty										
	Medical							125	2.9	0.9
	Surgical							84	2.8	1.1
	Service							41	3.1	0.7
	Missing							1	4.0	—

Note. The total number of correct responses to the four medical statistical literacy questions (range: 0–4). See the text for the classification of medical specialties.

BMJ Open

Assessing statistical literacy in medical students and doctors: a single-center, cross-sectional survey in South Korea

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-095173.R1
Article Type:	Original research
Date Submitted by the Author:	10-Mar-2025
Complete List of Authors:	Lee, Sun Young; Seoul National University Hospital, Public Healthcare Center; Seoul National University College of Medicine, Department of Human Systems Medicine Kim, Soela; Seoul National University Medical Research Center, Institute of Health Policy and Management Kim, Soyun; Seoul National University Medical Research Center, Institute of Health Policy and Management Shin, Yukyung; Sciences Po, Centre for the Sociology of Organisations Yim, Jae-Joon; Seoul National University College of Medicine, Department of Internal Medicine; Seoul National University Hospital, Division of Pulmonary and Critical Medicine, Department of Internal Medicine Hwang, Hyeontaek; Seoul National University College of Medicine, Department of Internal Medicine; Seoul National University Bundang Hospital, Division of Pulmonary and Critical Medicine, Department of Internal Medicine Kwon, Youngsuk; Seoul National University Hospital Kim, Un-Na; Seoul National University College of Medicine, Department of Health Policy and Management; Korea Ministry of Health and Welfare Do, Young Kyung; Seoul National University College of Medicine, Department of Health Policy and Management; Seoul National University Medical Research Center, Institute of Health Policy and Management
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Health services research
Keywords:	MEDICAL EDUCATION & TRAINING, Health Literacy, STATISTICS & RESEARCH METHODS, Surveys and Questionnaires

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Title Page

Assessing statistical literacy in medical students and doctors: a single-center, cross-sectional survey in South Korea

Sun Young Lee[1,2], Soela Kim[3], Soyun Kim[3], Yukyung Shin[4], Jae-Joon Yim[5,6], Hyeontaek Hwang[5,7], Youngsuk Kwon[8], Un-Na Kim[9, 10], Young Kyung Do[3,10*]

[1]Public Healthcare Center, Seoul National University Hospital

[2]Department of Human Systems Medicine, Seoul National University College of Medicine

[3]Institute of Health Policy and Management, Seoul National University Medical Research Center

[4]Centre for the Sociology of Organisations, Sciences Po

[5]Department of Internal Medicine, Seoul National University College of Medicine

[6]Division of Pulmonary and Critical Medicine, Department of Internal Medicine, Seoul National University Hospital

[7]Division of Pulmonary and Critical Medicine, Department of Internal Medicine, Seoul National University Bundang Hospital

[8]Seoul National University Hospital

[9]Ministry of Health and Welfare

[10]Department of Health Policy and Management, Seoul National University College of Medicine

*Corresponding author:

Young Kyung Do, M.D., M.P.H., Ph.D.

Department of Health Policy and Management

Seoul National University College of Medicine, South Korea.

Address: 103 Daehak-ro, Jongno-gu, Seoul 03080, Korea

E-mail: ykdo89@snu.ac.kr

Phone: +82-2-2072-3124

Fax: +82-2-743-2009

Assessing statistical literacy in medical students and doctors: a single-center, cross-sectional survey in South Korea

Abstract

Objective

Healthcare professionals must possess statistical literacy to provide evidence-based care and engage patients in decision-making. However, there have been concerns about healthcare professionals' inadequate understanding of health statistics. As an initial step in addressing the issue, we assessed the statistical literacy of medical students and doctors in South Korea by evaluating their comprehension of four statistical concepts: a) single-event probability, b) relative risk reduction, c) positive predictive value, and d) 5-year survival rate.

Design

Cross-sectional survey study

Setting

The survey was conducted from October 2018 to January 2019 in one medical school and one teaching hospital in Seoul, South Korea

Participants

303 medical students from one medical school and 291 doctors from one teaching hospital

Primary and secondary outcome measures

The primary outcome measure was the correct answer rate for each question. The secondary outcome measure was the mean number of correct answers across the four statistical literacy questions, calculated for each individual.

Results

The correct answer rates for basic numeracy questions were close to 100%. Regarding statistical literacy, 95.5% and 83.2% of the participants accurately understood single-event probability and relative risk reduction, respectively. However, only 49.3% and 49.2% of participants accurately understood the positive predictive value and 5-year survival rate,

respectively. The correct answer rates for the question about the 5-year survival rate differed significantly between students (40.9%) and doctors (57.7%) (p <.001). There were no statistically significant differences in the correct answer rates for other questions, regardless of the student's grade level or the doctor's specialty.

Conclusions

Medical students and doctors have weaker statistical literacy than their basic numeracy. Therefore, it is essential to implement medical education and professional development programs that focus on improving their statistical literacy. These programs should specifically address measures of medical test accuracy and the distinction between a 5-year survival rate and mortality.

Strengths and limitations of this study

- This study assessed the statistical literacy among medical students at different stages of their education.
- This study assessed the statistical literacy among practicing doctors across various clinical experiences and specialties.
- We measured statistical literacy using survey questions adapted to a more clinically relevant context.
- Participants were recruited from only a single medical school and one of its affiliated teaching hospitals in South Korea using a convenience sampling method.

Introduction

Statistical literacy in healthcare entails the ability to critically assess statistics in health information and understand statistical concepts in healthcare[1, 2]. This competency is essential for healthcare professionals practicing evidence-based medicine, where medical decisions are guided by the best available evidence—often numerically represented—alongside clinical expertise and patients' values and preferences [3, 4] For healthcare professionals, statistical literacy serves several critical functions. First, it enables the analysis and interpretation of emerging quantitative evidence about the benefits and risks of various healthcare options. Second, it allows for accurate statistical inferences from test results, aiding in accurate diagnosis and effective treatment planning.[4, 5] Third, it facilitates clear explanations of the implications of tests and treatments to patients, supporting informed, shared decision-making.[6] Without statistical literacy, healthcare professionals may struggle to provide optimal care and effectively involve patients in their healthcare decisions.

Despite the critical importance of statistical literacy in healthcare, numerous studies have identified common misunderstandings and errors among health professionals about statistical concepts.[5, 7-9] For example, healthcare professionals often struggle to comprehend and explain statistical concepts such as single-event probability (e.g., there is a 10% chance of an allergic reaction to a medication) and relative risk reduction (RRR, e.g., a new drug reduces the risk of having a heart attack by 60% when compared to a placebo).[2, 5, 7, 10] Moreover, medical students and doctors frequently find it challenging to understand conditional probabilities like sensitivity and specificity, and how to combine them with disease prevalence to estimate the positive predictive value (PPV: the conditional probability of having a disease when a test result is positive) [5, 11-20] Errors in estimating PPV can lead to severe consequences. Overestimating PPV can lead to overdiagnosis and overtreatment, causing unnecessary anxiety, costs, and harm to patients.[5, 18-21]. Conversely, underestimating PPV can result in missed opportunities for early intervention and worsen patient outcomes. Additionally, healthcare professionals often conflate an increase in the 5-

year survival rate with a reduction in mortality, even though these statistics measure different aspects of clinical and epidemiological data.[15, 22] The 5-year survival rate represents the proportion of individuals who survive five years after being diagnosed with an illness, whereas mortality refers to the annual rate of disease-related deaths within a given population. Screening asymptomatic individuals can increase the 5-year survival rate by detecting the disease earlier, but it may not reduce mortality if the disease progression or treatment outcomes are unaffected. Therefore, relying solely on a 5-year survival rate, or confusing it with mortality, can misrepresent the life-saving benefits of screening programs.[10, 15, 22, 23] As evidenced in these widespread misunderstandings of fundamental statistical concepts, the lack of statistical health literacy among healthcare professionals not only impedes accurate assessment of medical interventions but also potentially compromises the overall effectiveness of evidence-based medicine. [1, 5, 22, 24]

Although statistical literacy, like other medical knowledge and clinical skills, can affect patient health outcomes, the medical education community often overlooks the importance of continuously enhancing formal training to foster statistical literacy. To introduce improved formal training to medical students and doctors, it is imperative to assess their current statistical literacy on major clinical issues highlighted in the literature and identify areas for improvement. For a notable example, a study from Germany assessed the minimum statistical literacy of 169 final-year medical students, measuring their understanding of 10 basic statistics concepts, including sensitivity, specificity, PPV, RRR, and mortality.[2] The students' median percentage of correct answers to these questions was 50% before brief training, which increased to 90% afterward.

We aimed to assess the statistical literacy of medical students and doctors in South Korea, combining the conceptual components of the German study and adapting them to a more clinically relevant context.[2] When assessing statistical literacy, we focused on understanding four key statistical concepts: a) single-event probability, b) RRR, c) PPV, and d) 5-year survival rate. We also assessed their basic numeracy (i.e., an elementary skill to

understand and use numbers), which may be a prerequisite for statistical literacy.[5] This assessment will help identify which statistical concepts are most challenging for our target population and guide the development of improved medical education.

Methods

Study setting

Between October 2018 and January 2019, we conducted a cross-sectional survey among a convenience sample of medical students from a single medical school and doctors from one of its affiliated public teaching hospitals in Seoul, South Korea. South Korean medical education consists of a comprehensive 6-year program. The medical school conducting this study admits approximately 135 students per academic year, with students completing their clinical clerkships at affiliated research hospitals in their fifth and sixth years. The teaching hospital has a capacity of 1,800 beds and serves a significant patient population, handling 2.4 million outpatient visits and 560,000 inpatients each year. Medical students from all six years of the program, trainee doctors (interns and residents), and attending physicians at the hospital were eligible to participate in the study. We contacted student organizations and resident physicians to inform them about the study and sought their assistance in recruiting participants. Co-investigators, who were medical students or doctors-in-training themselves, approached potential participants before and after events, such as meetings, classes, and conferences that many students and doctors attended. They explained the study and invited individuals to participate. Participants who agreed were given a questionnaire on the spot. The entire questionnaire included two separate thematic sections: medical statistical literacy (the focus of this paper) and patient-centeredness (not reported in this paper) along with key demographic information, such as gender, age, students' year of study or doctor's grade and specialty. The questionnaire took approximately 5–10 minutes to complete. Participants received a gift card worth around 4 USD as a token of appreciation. This study was approved by the Institutional Review Board of Seoul National University (IRB No. 1808-185-969).

Sample

Our use of convenience sampling from a single medical school and teaching hospital may limit the generalizability of our findings. To mitigate this, we aimed for a diverse sample across different years of study for students and different specialties for doctors. For medical students, our goal was to survey approximately one-third of students in each grade of the six-year medical school program, targeting 50 students per year for a total student sample of 300. Due to the expected challenges in surveying hospital doctors, we targeted approximately one-fourth of the trainee doctors, including both one-year interns and three- or four-year residents, as well as 100 attending physicians from a total of nearly 900. Since interns are not yet affiliated with a specialty, specialty information was collected only from residents and attending physicians. We aimed to survey residents and attending physicians from 13 specialties out of the 23 clinical specialties, which we classified into three main groups: medical (internal medicine, pediatrics, rehabilitation, family medicine, and psychiatry), surgical (emergency medicine, obstetrics and gynecology, orthopedics, otorhinolaryngology, and general surgery), and service (radiology, laboratory medicine, and anesthesiology). The approximate proportion of these groups in our sample was set to 5:3:2 for residents and attending physicians, reflecting the proportion of residency openings in these specialties in 2019. See Supplementary Table 1 for the target and actual numbers of participants.

Measures

To assess basic numeracy, we used three fill-in-the-blank questions previously designed to measure basic numeracy across various populations in prior studies.[5, 25] These questions involved converting between percentages and frequencies and interpreting chance outcomes. To assess statistical literacy, we developed four questions based on two previous studies regarding the statistical literacy of medical students and professionals that identified four commonly misunderstood statistical concepts: single-event probability, RRR, PPV, and 5-year survival rate.[2, 5] Our research team, consisting of experts in clinical medicine and medical education, initially formulated questions to evaluate comprehension of the four

concepts based on their definitions. The question on single-event probability was included as it is often confusing due to the lack of a reference class, causing diverse misunderstandings. The RRR question aimed to assess participants' ability to explain this concept in the context of comparing new versus conventional chemotherapy. The PPV question involved calculating the probability of having breast cancer given a positive mammogram result, using information on sensitivity, specificity, and prevalence. The question on the 5-year survival rate was framed around the increased survival rates of thyroid cancer in South Korea to evaluate participants' understanding of the distinction between increased survival and reduced mortality.[5, 23] The wording of the formulated questions was further refined through an iterative process involving both medical students and physicians to improve readability and real-world clinical relevance. The final set of questions was evaluated and revised until consensus was reached. See Box 1 for an English translation of the exact wording of the questions and response options.

[Insert Box 1 about here]

Statistical analysis

The collected data was converted into an anonymized database and analyzed. The percentage of correct answers for each basic numeracy and statistical literacy question was computed. We analyzed the percentage of correct answers for medical students and doctors for the four statistical literacy questions, examining variations by students' grades and doctors' specialty. Differences between subgroups were compared using the chi-square test for two groups and ANOVA for three groups. All statistical analyses were conducted using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). *P*-values were based on a two-sided significance level of 0.05.

Patient and public involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study.

Results

A total of 303 medical students and 291 doctors participated in the survey. Table 1 presents the characteristics of the participants.

[Insert Table 1 about here]

The correct answer rate for all three basic numeracy questions was close to 100% in both the student and doctor groups (Figure 1). The first two statistical literacy questions—the single-event probability question and the RRR question—also had high correct answer rates, approximately 95% and 83%, respectively. However, the PPV question and the 5-year survival rate question had much lower correct answer rates, approximately 49%. There was no notable difference in correct answer rates between medical students and doctors, except for the 5-year survival rate question, where doctors had a higher correct answer rate (57.7%) than medical students (40.9%, $p < 0.001$). See Supplementary Table 2 for the distributions of answer choices selected for each statistical literacy question.

[Insert Figure 1 about here]

Figure 2 presents the percentage of correct answers given by medical students at different grade levels for statistical literacy questions. In general, the correct answer rate increased with grade level, although the observed differences were not statistically significant. For instance, 46.6% of the third- and fourth-year medical students answered the 5-year survival rate question correctly, compared to 38.0% of the premedical and first- and second-year medical students.

[Insert Figure 2 about here]

Doctors in service specialties consistently demonstrated higher correct answer rates than those in medical or surgical specialties, although these differences were not statistically significant (Figure 3). Notably, the correct answer rate for the PPV question was higher among doctors in service specialties (56.1%) compared to their peers in medical (48.8%) and surgical (47.6%) specialties. The overall mean score on the four statistical literacy questions was also slightly higher among doctors in service specialties (Supplementary Table 3).

[Insert Figure 3 about here]

Discussion

Despite their high basic numeracy, the medical students and doctors in this study demonstrated areas for improvement in key aspects of statistical literacy. While over 80% of participants correctly answered questions on single-event probability and RRR, correct answer rates were substantially lower for the PPV and 5-year survival rate questions. Both groups performed similarly on most questions, except for the 5-year survival question, where medical students had a significantly lower correct answer rate than doctors. Notably, increasing years in medical school did not result in considerably higher correct answer rates.

While this study may offer only a snapshot of the statistical literacy of Korean medical students and doctors, it serves as a window to examine the current state of medical education concerning statistical literacy in South Korea and beyond. Since the students and doctors in this study possessed high basic numeracy skills, their underdeveloped statistical literacy cannot be attributed to their basic numeracy. The two questions about statistical literacy, single-event probability and RRR, had high correct answer rates. This could be mainly because they are more closely related to basic numeracy compared to the other two questions, PPV and 5-year survival rate. These are areas where medical education can play an important role. Previous studies have linked insufficient statistical literacy in doctors to a non-transparent presentation of statistical information and to medical schools that do not give adequate attention to the importance of teaching risk communication.[2, 5] Therefore, it is crucial to introduce medical education and professional development programs that enhance statistical literacy among medical students and doctors. In these programs, the main focus should be on enhancing the ability to make statistical inferences from medical test results and to acquire proficiency in using relevant medical statistics to critically evaluate the effects of illness and the life-saving advantages of medical treatments. The following discussion focuses on the two areas—PPV and 5-year survival rate, where there is a large room for

improvement, as demonstrated in this study.

Although the medical students and doctors in this study had a significantly higher accuracy rate (approximately 49%) in answering the PPV question compared to their counterparts in previous German studies (approximately 20%)[2, 5], this rate is still far from satisfactory, particularly from a medical education standpoint. Our results indicated that being in higher years in medical school and even currently practicing medicine as a doctor was not associated with higher correct answer rates for the PPV question, suggesting both undergraduate and postgraduate medical education could improve significantly. Participants might have confused the PPV with sensitivity,[13] which was presented as 90% in the question. Alternatively, the tendency to overestimate PPVs, as observed in previous studies, [12, 16, 26, 27] might have led to the incorrect answer. Regardless of which explanation is more plausible, it is important to remember that overestimating PPVs of medical tests can lead to further tests, unnecessary treatments, and potential patient harm.[5] There is ample evidence that presenting statistical information in the form of natural frequencies rather than probabilities can improve conditional probabilistic reasoning, as it helps with an intuitive understanding of conditional probabilities[8, 17, 28-31]. The observed effect of the natural frequency format was evident in individuals with both high and low numeracy.[29, 32] Furthermore, studies have shown that teaching medical students and doctors how to translate relevant statistical information presented in probabilities into natural frequencies also facilitates conditional probabilistic reasoning.[5, 28, 33, 34] . However, given that statistical literacy skills improved after training can deteriorate within one to two months without reinforcement, medical schools and boards should implement regular statistical training and assessments to maintain these crucial competencies.[9, 35] It would be helpful to incorporate these research findings more actively when developing training programs to improve medical students' and doctors' ability to estimate the predictive values of medical tests.

Another major weak area in statistical literacy identified in this study was the confusion between 5-year survival rate and mortality. Almost half of medical students and

one-third of doctors in this study incorrectly believed that an increase in the 5-year survival rate of thyroid cancer indicates a decrease in mortality from the disease. The relatively higher correct answer rate among doctors compared to medical students is likely due to their experience in clinical practice, where the concepts of 5-year survival rates and mortality are frequently used and compared. Nevertheless, the correct answer rate was still less than 60% among doctors and even lower among medical students, which is concerning because these two concepts must be carefully distinguished when assessing the impact of illness and the life-saving benefits of medical interventions.[5, 23] Otherwise, healthcare professionals may overestimate the life-saving advantages of cancer screening, which could explain the overutilization of low-value cancer screenings and the overdiagnosis of cancer. This misunderstanding has far-reaching consequences. Indeed, the overuse of low-value cancer screenings is contributing to cancer overdiagnosis and overtreatment globally, with South Korea being a particularly notable example of this trend.[36-38] When teaching about the 5-year survival rate and mortality, it is critical to emphasize their key difference: the denominators used in their calculation. For 5-year survival rate, the denominator is the number of people diagnosed with the disease, whereas for mortality rate, it is the number of people in the general population.[23, 39] Understanding this distinction is essential for correctly interpreting these statistics in medical contexts. Utilizing visual aids such as bar charts or pie charts can be helpful. These graphics could separately show (i) the proportion of people who survived for five years after being diagnosed with a certain disease (5-year survival rate), and (ii) the annual rate of disease-related deaths in the population (mortality rate). Such visual representations can also facilitate comparing these rates across different populations or groups.[21]

This study has several limitations. First, we recruited participants from only a single medical school and a teaching hospital in South Korea using a convenient sampling method. This approach may have introduced selection bias, potentially limiting the generalizability of our findings beyond the specific institutions involved to the broader population of medical

students and doctors across South Korea. Additionally, participants who chose to respond to our survey might have different statistical literacy characteristics than those who didn't participate. This could lead to overestimating statistical literacy if those who felt more confident in their abilities were more likely to participate. Second, while our work focused on key weak areas of statistical literacy among medical students and doctors as highlighted in previous research [2, 5], it must be explicitly acknowledged that the questionnaire does not comprehensively cover all aspects of statistical literacy relevant to medical practice, as one would expect from a validated instrument. Third, we did not investigate factors that may influence statistical literacy beyond examining its associations with basic characteristics available in the data.

Despite these limitations, this study provides the first assessment of the statistical literacy of Korean medical students in varying grades and doctors with varying clinical experience and specialties. Based on the findings of this study, we designed and carried out an educational intervention aimed at improving medical students' statistical literacy, that is necessary to understand medical statistics and critically assess the available scientific evidence. We believe that this study will inspire further research in improving medical education regarding statistical literacy in South Korea and other countries.

Acknowledgments: We thank the medical students and doctors who voluntarily participated in this study.

Funding: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2018R1A2B2009257). The funder was not involved in the design of the study, the collection, analysis, and interpretation of data, or in writing the submitted work.

Conflict of interest: The authors have declared that no competing interests exist.

Ethical approval: This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1808-185-969) and informed consent was obtained from the participants.

Authors' contribution

SYL, UNK, and YKD developed the questionnaire. SYL, YS, JJY, HH, YK, and YKD contributed to data collection. SYL conducted the statistical analysis and wrote the first draft of the manuscript. SYL, Soela K, Soyun K, and YKD critically reviewed and revised earlier drafts. All authors reviewed and provided input during the revision process. YKD secured funding for this study. YKD is the guarantor of the study.

Data sharing statement

The datasets used in the current study are available from the corresponding author upon reasonable request.

Box 1. Questionnaire to assess basic numeracy and medical statistical literacy

Basic Numeracy

BN Q1. People who take drug A have a 1% chance of having an allergic reaction. If 1000 people take drug A, how many people are expected to have an allergic reaction?
Answer: _____ out of 1000 (*Correct answer: 10*)

BN Q2. 1 out of 1000 people who take drug B may have an allergic reaction. What percentage of people who take drug B are expected to have an allergic reaction?
Answer: _____ % (*Correct answer: 0.1*)

BN Q3. Suppose that a coin is tossed 1000 times. How many times do you expect to get heads out of 1000 attempts?
Answer: About _____ times out of 1000 (*Correct answer: 500*)

Statistical Literacy

SL Q1. Antidepressant C has a 20% risk of causing weight gain. Which of the following is the most correct explanation? (*Single-event probability*)
a. Patients with depression who take C have a 20% increase in weight.
b. 2 out of 10 patients with depression who take C experience weight gain. ***
c. If you take 10 pills of C, 2 of them have a risk of causing weight gain.
d. If you take C for 10 months, you are at risk of weight gain for 2 months.

SL Q2. A new chemotherapy drug reduces the risk of vomiting (as a side effect) by 60% compared to conventional chemotherapy. Which of the following is the most correct explanation? (*Relative risk reduction*)
a. When using the new chemotherapy, the risk of vomiting is reduced to 40%.
b. When using the new chemotherapy, vomiting occurs in 40 of 100 patients.
c. Among 100 patients, the number of patients experiencing vomiting is reduced by 60 when using the new chemotherapy compared to conventional chemotherapy.
d. If vomiting occurs in 50 out of 100 patients when using conventional chemotherapy, vomiting occurs in 20 out of 100 patients when using the new chemotherapy. ***

SL Q3. The prevalence of breast cancer for women in their 60s is 1%. A woman with breast cancer has a 90% chance of being positive on a mammogram, and a woman without breast cancer has a 9% chance of testing positive on a mammogram. Which of the following is the closest to the probability that a woman with a positive mammogram actually has breast cancer? (*Positive predictive value*)
a. 81%
b. 9 out of 10
c. 1 out of 10 ***
d. 1%

SL Q4. The 5-year survival rate of thyroid cancer in South Korea has improved compared to the past. Which of the following is the most correct explanation? (*5-year survival rate*)
a. It is possible that the incidence of thyroid cancer has decreased.
b. An improvement in the 5-year survival rate of thyroid cancer means an improvement in the cure rate of thyroid cancer.
c. An improvement in the 5-year survival rate of thyroid cancer means a reduction in mortality due to thyroid cancer.
d. Early detection of thyroid cancer may increase the 5-year survival rate, but may not reduce mortality. ***

Notes. *** denotes the correct answer. The questionnaire was administered in Korean; this is an English translation. Italicized words were not included in the questionnaire but are shown here for clarity.

17

Table 1. Characteristics of study participants

		Total (N=594)		Medical Students (n=303)		Doctors (n=291)	
		n	%	n	%	n	%
Age group							
	–19	37	6.2	37	12.2	0	0.0
	20–29	371	62.5	265	87.5	106	36.4
	30–39	140	23.6	1	0.3	139	47.8
	40–49	44	7.4	0	0.0	44	15.1
	50+	2	0.3	0	0.0	2	0.7
Gender							
	Male	355	59.8	179	59.1	176	60.5
	Female	239	40.2	124	40.9	115	39.5
Student's grade							
	Premedical			100	33.0		
	Medical			203	67.0		
Doctor's grade							
	Intern					40	13.7
	Resident					146	50.2
	Attending					105	36.1
Doctor's specialty							
	Medical					125	43.0
	Surgical					84	28.9
	Service					41	14.1
	Missing					1	0.3

Note. See the text for the classification of medical specialties.

References

1. Gigerenzer, G. and J.A.M. Gray, *Launching the Century of the Patient*, in *Better Doctors, Better Patients, Better Decisions*, G. Gigerenzer and J.A.M. Gray, Editors. 2011, The MIT Press. p. 3-28.
2. Jenny, M.A., N. Keller, and G. Gigerenzer, *Assessing minimal medical statistical literacy using the Quick Risk Test: a prospective observational study in Germany.* BMJ open, 2018. **8**(8): p. e020847.
3. Monahan, J., *Statistical literacy: A prerequisite for evidence-based medicine*. 2007, SAGE Publications Sage CA: Los Angeles, CA. p. i-ii.
4. Schmidt, F.M., et al., *Statistical literacy and scientific reasoning & argumentation in physicians.* GMS Journal for Medical Education, 2021. **38**(4).
5. Gigerenzer, G., et al., *Helping doctors and patients make sense of health statistics.* Psychological science in the public interest, 2007. **8**(2): p. 53-96.
6. Osborn, C.Y., *Shared decision making requires statistical literacy.* AMA Journal of Ethics, 2009. **11**(4): p. 301-305.
7. Gigerenzer, G., *Better doctors, better patients, better decisions.* 2014.
8. Lakhlifi, C., et al., *Illusion of knowledge in statistics among clinicians: evaluating the alignment between objective accuracy and subjective confidence, an online survey.* Cognitive Research: Principles and Implications, 2023. **8**(1): p. 23.
9. Soto-Mota, A., et al., *Evaluation of statistical illiteracy in Latin American clinicians and the piloting evaluation of a short course across multiple timepoints.* BMC Medical Education, 2022. **22**(1): p. 54.
10. Gigerenzer, G., *Making sense of health statistics.* Bull World Health Organ, 2009. **87**(8): p. 567.
11. Bramwell, R., H. West, and P. Salmon, *Health professionals' and service users' interpretation of screening test results: experimental study.* BMJ, 2006. **333**(7562): p. 284.
12. Casscells, W., A. Schoenberger, and T.B. Graboys, *Interpretation by Physicians of Clinical Laboratory Results.* N Engl J Med, 1978. **299**(18): p. 999-1001.
13. Eddy, D.M., *Probabilistic reasoning in clinical medicine: Problems and opportunities*, in *Judgment under uncertainty: Heuristics and biases* D. Kahneman, P. Slovic, and A. Tversky, Editors. 1982, Cambridge University Press: Cambridge. p. 249-267.
14. Wegwarth, O. and G. Gigerenzer, *US gynecologists' estimates and beliefs regarding ovarian cancer screening's effectiveness 5 years after release of the PLCO evidence.* Scientific reports, 2018. **8**(1): p. 17181.
15. Wegwarth, O., et al., *Do physicians understand cancer screening statistics? A national survey of primary care physicians in the United States.* Annals of internal medicine, 2012. **156**(5): p. 340-349.
16. Whiting, P.F., et al., *How well do health professionals interpret diagnostic information? A systematic review.* BMJ Open, 2015. **5**(7): p. e008155.
17. Hoffrage, U. and G. Gigerenzer, *Using natural frequencies to improve diagnostic inferences.* Acad Med, 1998. **73**(5): p. 538-540.
18. Aronowitz, R. and J.A. Greene, *Contingent knowledge and looping effects—a 66-year-old man with PSA-detected prostate cancer and regrets.* N Engl J Med, 2019.
19. Gigerenzer, G., *HIV screening: helping clinicians make sense of test results to patients.* BMJ, 2013. **347**: p. f5151.
20. Gigerenzer, G., U. Hoffrage, and A. Ebert, *AIDS counselling for low-risk clients.* Aids Care, 1998. **10**(2): p. 197-211.
21. Fagerlin, A., B.J. Zikmund-Fisher, and P.A. Ubel, *Helping Patients Decide: Ten Steps to Better Risk Communication.* JNCI: Journal of the National Cancer Institute, 2011. **103**(19): p. 1436-1443.
22. Wegwarth, O., W. Gaissmaier, and G. Gigerenzer, *Deceiving numbers: survival rates and their impact on doctors' risk communication.* Med Decis Making, 2011. **31**(3): p.

386-94.

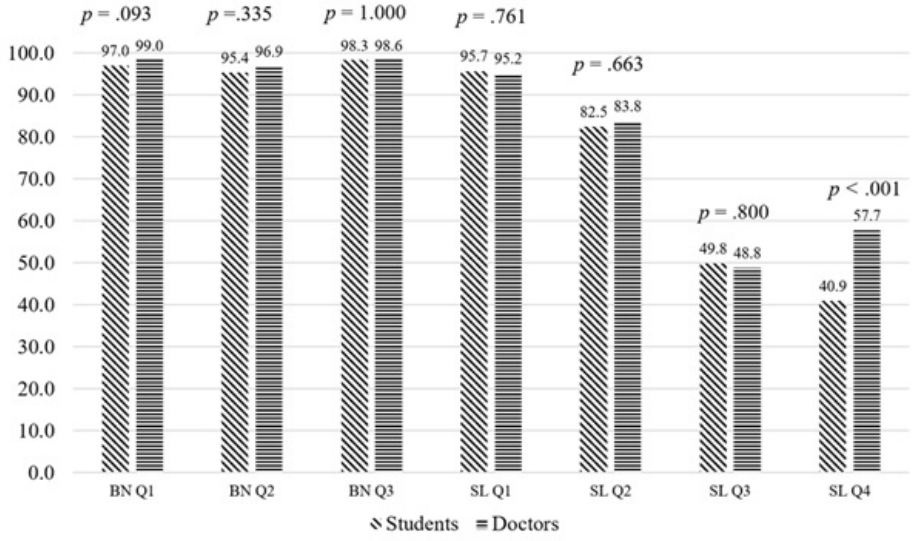
23. Welch, H.G., L.M. Schwartz, and S. Woloshin, *Are increasing 5-year survival rates evidence of success against cancer?* Jama, 2000. **283**(22): p. 2975-2978.
24. Petrova, D., et al., *Cancer screening risk literacy of physicians in training: An experimental study.* PLOS ONE, 2019. **14**(7): p. e0218821.
25. Schwartz, L.M., et al., *The role of numeracy in understanding the benefit of screening mammography.* Annals of internal medicine, 1997. **127**(11): p. 966-972.
26. Manrai, A.K., et al., *Medicine's uncomfortable relationship with math: calculating positive predictive value.* JAMA Intern Med, 2014. **174**(6): p. 991-993.
27. Lyman, G.H. and L. Balducci, *Overestimation of test effects in clinical judgment.* J Cancer Educ, 1993. **8**(4): p. 297-307.
28. Feufel, M.A., et al., *Boosting for insight and/or boosting for agency? How to maximize accurate test interpretation with natural frequencies.* BMC Medical Education, 2023. **23**(1): p. 75.
29. Galesic, M., G. Gigerenzer, and N. Straubinger, *Natural frequencies help older adults and people with low numeracy to evaluate medical screening tests.* Medical Decision Making, 2009. **29**(3): p. 368-371.
30. Gigerenzer, G., *What are natural frequencies?* Bmj, 2011. **343**: p. d6386.
31. McDowell, M. and P. Jacobs, *Meta-analysis of the effect of natural frequencies on Bayesian reasoning.* Psychological bulletin, 2017. **143**(12): p. 1273.
32. Chapman, G.B. and J. Liu, *Numeracy, frequency, and Bayesian reasoning.* Judgment and Decision Making, 2009. **4**(1): p. 34-40.
33. Sedlmeier, P. and G. Gigerenzer, *Teaching Bayesian reasoning in less than two hours.* J Exp Psychol Gen, 2001. **130**(3): p. 380-400.
34. Kurzenhäuser, S. and U. Hoffrage, *Teaching Bayesian reasoning: an evaluation of a classroom tutorial for medical students.* Med Teach, 2002. **24**(5): p. 516-521.
35. Kim, S., et al., *Natural frequency tree-versus conditional probability formula-based training for medical students' estimation of screening test predictive values: a randomized controlled trial.* BMC Medical Education, 2024. **24**(1): p. 1207.
36. Li, M., L. Dal Maso, and S. Vaccarella, *Global trends in thyroid cancer incidence and the impact of overdiagnosis.* The Lancet Diabetes & Endocrinology, 2020. **8**(6): p. 468-470.
37. Ahn, H.S., H.J. Kim, and H.G. Welch, *Korea's thyroid-cancer "epidemic"—screening and overdiagnosis.* N Engl J Med, 2014. **371**(19): p. 1765-1767.
38. Lee, J.-H. and S.W. Shin, *Overdiagnosis and screening for thyroid cancer in Korea.* The Lancet, 2014. **384**(9957): p. 1848.
39. Gigerenzer, G. and O. Wegwarth, *Five year survival rates can mislead.* BMJ: British Medical Journal (Online), 2013. **346**.

Figure legends

Figure 1. Correct answer rates for basic numeracy and medical statistical literacy questions

Figure 2. Correct answer rates for medical statistical literacy questions by student grade

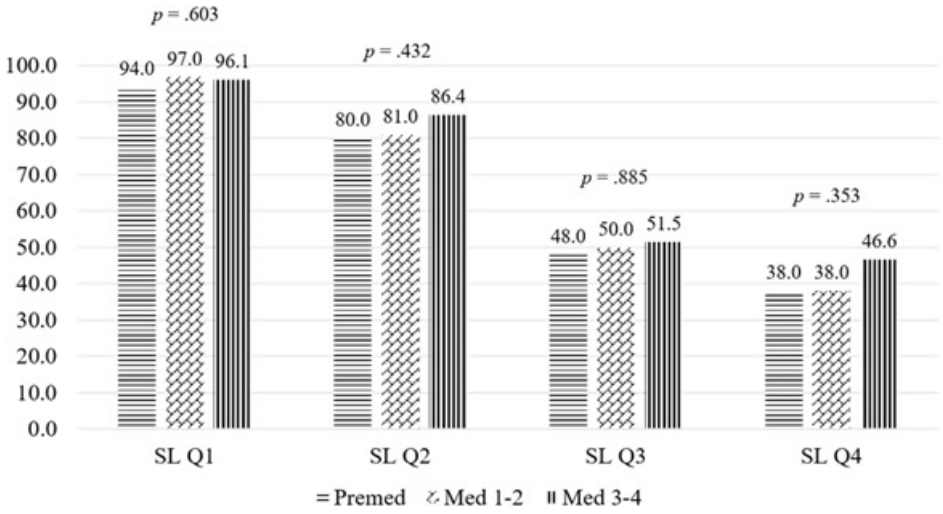
Figure 3. Correct answer rates for medical statistical literacy questions by specialty



Notes. BN Q1: Converting a percent to a proportion, BN Q2: Converting a proportion to a percent, BN Q3: Familiarity with chance outcome, SL Q1: Single-event probability, SL Q2: Relative risk reduction, SL Q3: Positive predictive value, SL Q4: 5-year survival rate.

Correct answer rates for basic numeracy and medical statistical literacy questions

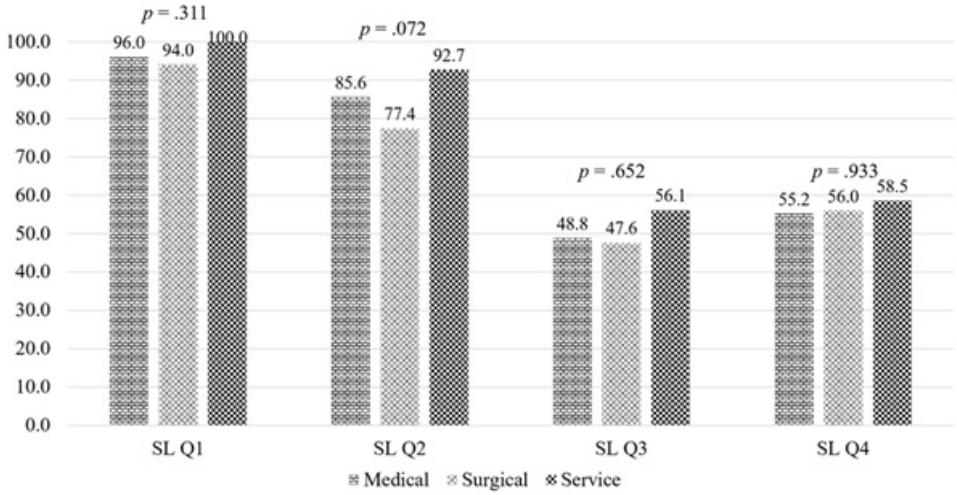
171x117mm (96 x 96 DPI)



Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate.

Correct answer rates for medical statistical literacy questions by student grade

164x103mm (96 x 96 DPI)



Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate. See the text for the classification of medical specialties. Interns are not included in this analysis. The response from one attending physician who did not specify specialty was excluded from the analysis.

Correct answer rates for medical statistical literacy questions by specialty

164x108mm (96 x 96 DPI)

Assessing statistical literacy in medical students and doctors: a survey in South Korea

Supplementary Table 1. Target and actual numbers of participants

			Target number of participants	Actual number of participants	% of goal
Student	Premedical	1st year	50	50	100.0
		2nd year	50	50	100.0
	Medical	1st year	50	50	100.0
		2nd year	50	50	100.0
		3rd year	50	53	106.0
		4th year	50	50	100.0
	Total		300	303	101.0
Doctor	Intern	—	40	40	100.0
	Resident	Medical	68	68	100.0
		Surgical	40	51	127.5
		Service	24	26	108.3
	Attending	Medical	62	57	91.9
		Surgical	30	33	110.0
		Service	16	15	93.8
		Missing	—	1	—
	Total		280	291	103.9
Total			580	594	102.4

Note. See the text for the classification of medical specialties.

2

Supplementary Table 2. Distribution of answer choices selected to medical statistical literacy questions by medical students and doctors (%)

Choice	Single-event probability		Relative risk reduction		Positive predictive value		5-year survival rate	
	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)
1	1.7	2.1	5.0	4.8	11.6	15.8	1.7	0.3
2	**95.7**	**95.2**	0.3	0.0	24.8	25.1	8.3	9.6
3	2.3	2.7	12.2	11.3	**49.8**	**48.8**	49.2	32.3
4	0.3	0.0	**82.5**	**83.8**	13.5	10.0	**40.9**	**57.7**
Missing					0.3			

Notes: The correct answers are in bold.

Supplementary Table 3. Mean scores of medical statistical literacy by characteristics of study participants

		Total (N=594)			Medical Students (n=303)			Doctors (n=291)		
		n	Mean	*SD*	n	Mean	*SD*	n	Mean	*SD*
Total			2.8	0.9		2.7	0.9		2.9	1.0
Age group										
	–19	37	2.4	0.9	37	2.4	0.9			
	20–29	371	2.8	0.9	265	2.7	0.9	106	3.1	1.0
	30–39	140	2.6	0.9	1	4.0	—	139	2.6	0.9
	40–49	44	3.1	0.9				44	3.1	0.9
	50+	2	3.0	1.4				2	3.0	1.4
Gender										
	Male	355	2.9	0.9	179	2.8	0.9	176	3.0	1.0
	Female	239	2.6	0.9	124	2.5	0.9	115	2.7	0.9
Student's grade										
	Premedical				100	2.6	0.9			
	Medical				203	2.7	0.9			
Doctor's grade										
	Intern							40	2.8	1.2
	Resident							146	2.8	1.0
	Attending							105	3.0	0.8
Doctor's specialty										
	Medical							125	2.9	0.9
	Surgical							84	2.8	1.1
	Service							41	3.1	0.7
	Missing							1	4.0	—

Note. The total number of correct responses to the four medical statistical literacy questions (range: 0–4). See the text for the classification of medical specialties.

BMJ Open

Assessing statistical literacy in medical students and doctors: a single-centre, cross-sectional survey in South Korea

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2024-095173.R2
Article Type:	Original research
Date Submitted by the Author:	19-Mar-2025
Complete List of Authors:	Lee, Sun Young; Seoul National University Hospital, Public Healthcare Center; Seoul National University College of Medicine, Department of Human Systems Medicine Kim, Soela; Seoul National University Medical Research Center, Institute of Health Policy and Management Kim, Soyun; Seoul National University Medical Research Center, Institute of Health Policy and Management Shin, Yukyung; Sciences Po, Centre for the Sociology of Organisations Yim, Jae-Joon; Seoul National University College of Medicine, Department of Internal Medicine; Seoul National University Hospital, Division of Pulmonary and Critical Medicine, Department of Internal Medicine Hwang, Hyeontaek; Seoul National University College of Medicine, Department of Internal Medicine; Seoul National University Bundang Hospital, Division of Pulmonary and Critical Medicine, Department of Internal Medicine Kwon, Youngsuk; Seoul National University Hospital Kim, Un-Na; Seoul National University College of Medicine, Department of Health Policy and Management; Korea Ministry of Health and Welfare Do, Young Kyung; Seoul National University College of Medicine, Department of Health Policy and Management; Seoul National University Medical Research Center, Institute of Health Policy and Management
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Epidemiology
Keywords:	MEDICAL EDUCATION & TRAINING, Health Literacy, STATISTICS & RESEARCH METHODS, Surveys and Questionnaires

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Title Page

Assessing statistical literacy in medical students and doctors: a single-centre, cross-sectional survey in South Korea

Sun Young Lee[1,2], Soela Kim[3], Soyun Kim[3], Yukyung Shin[4], Jae-Joon Yim[5,6], Hyeontaek Hwang[5,7], Youngsuk Kwon[8], Un-Na Kim[9, 10], Young Kyung Do[3,10*]

[1]Public Healthcare Center, Seoul National University Hospital

[2]Department of Human Systems Medicine, Seoul National University College of Medicine

[3]Institute of Health Policy and Management, Seoul National University Medical Research Center

[4]Centre for the Sociology of Organisations, Sciences Po

[5]Department of Internal Medicine, Seoul National University College of Medicine

[6]Division of Pulmonary and Critical Medicine, Department of Internal Medicine, Seoul National University Hospital

[7]Division of Pulmonary and Critical Medicine, Department of Internal Medicine, Seoul National University Bundang Hospital

[8]Seoul National University Hospital

[9]Ministry of Health and Welfare

[10]Department of Health Policy and Management, Seoul National University College of Medicine

*Corresponding author:

Young Kyung Do, M.D., M.P.H., Ph.D.

Department of Health Policy and Management

Seoul National University College of Medicine, South Korea.

Address: 103 Daehak-ro, Jongno-gu, Seoul 03080, Korea

E-mail: ykdo89@snu.ac.kr

Phone: +82-2-2072-3124

Fax: +82-2-743-2009

Assessing statistical literacy in medical students and doctors: a single-centre, cross-sectional survey in South Korea

Abstract

Objective

Healthcare professionals must possess statistical literacy to provide evidence-based care and engage patients in decision-making. However, there have been concerns about healthcare professionals' inadequate understanding of health statistics. As an initial step in addressing the issue, we assessed the statistical literacy of medical students and doctors in South Korea by evaluating their comprehension of four statistical concepts: a) single-event probability, b) relative risk reduction, c) positive predictive value, and d) 5-year survival rate.

Design

Cross-sectional survey study

Setting

The survey was conducted from October 2018 to January 2019 in one medical school and its affiliated teaching hospital in Seoul, South Korea

Participants

303 medical students from all six grades and 291 doctors from various specialties

Primary and secondary outcome measures

The primary outcome measure was the correct answer rate for each question. The secondary outcome measure was the mean number of correct answers across the four statistical literacy questions, calculated for each individual.

Results

The correct answer rates for basic numeracy questions were close to 100%. Regarding statistical literacy, 95.5% and 83.2% of the participants accurately understood single-event probability and relative risk reduction, respectively. However, only 49.3% and 49.2% of participants accurately understood the positive predictive value and 5-year survival rate,

respectively. The correct answer rates for the question about the 5-year survival rate differed significantly between students (40.9%) and doctors (57.7%) (p <.001). There were no statistically significant differences in the correct answer rates for other questions, regardless of the student's grade level or the doctor's specialty.

Conclusions

Medical students and doctors have weaker statistical literacy than their basic numeracy. Therefore, it is essential to implement medical education and professional development programs that focus on improving their statistical literacy. These programs should specifically address measures of medical test accuracy and the distinction between a 5-year survival rate and mortality.

Strengths and limitations of this study

- This study assessed the statistical literacy among medical students at different stages of their education.
- This study assessed the statistical literacy among practicing doctors across various clinical experiences and specialties.
- We measured statistical literacy using survey questions adapted to a more clinically relevant context.
- Participants were recruited from only a single medical school and its affiliated teaching hospital in South Korea using a convenience sampling method.

Introduction

Statistical literacy in healthcare entails the ability to critically assess statistics in health information and understand statistical concepts in healthcare.[1 2] This competency is essential for healthcare professionals practicing evidence-based medicine, where medical decisions are guided by the best available evidence—often numerically represented—alongside clinical expertise and patients' values and preferences [3 4] For healthcare professionals, statistical literacy serves several critical functions. First, it enables the analysis and interpretation of emerging quantitative evidence about the benefits and risks of various healthcare options. Second, it allows for accurate statistical inferences from test results, aiding in accurate diagnosis and effective treatment planning.[4 5] Third, it facilitates clear explanations of the implications of tests and treatments to patients, supporting informed, shared decision-making.[6] Without statistical literacy, healthcare professionals may struggle to provide optimal care and effectively involve patients in their healthcare decisions.

Despite the critical importance of statistical literacy in healthcare, numerous studies have identified common misunderstandings and errors among health professionals about statistical concepts.[5 7-9] For example, healthcare professionals often struggle to comprehend and explain statistical concepts such as single-event probability (e.g., there is a 10% chance of an allergic reaction to a medication) and relative risk reduction (RRR, e.g., a new drug reduces the risk of having a heart attack by 60% when compared to a placebo).[2 5 7 10] Moreover, medical students and doctors frequently find it challenging to understand conditional probabilities like sensitivity and specificity, and how to combine them with disease prevalence to estimate the positive predictive value (PPV: the conditional probability of having a disease when a test result is positive) [5 11-20] Errors in estimating PPV can lead to severe consequences. Overestimating PPV can lead to overdiagnosis and overtreatment, causing unnecessary anxiety, costs, and harm to patients.[5 18-21]. Conversely, underestimating PPV can result in missed opportunities for early intervention and worsen patient outcomes. Additionally, healthcare professionals often conflate an increase in the 5-year survival rate

with a reduction in mortality, even though these statistics measure different aspects of clinical and epidemiological data.[15 22] The 5-year survival rate represents the proportion of individuals who survive five years after being diagnosed with an illness, whereas mortality refers to the annual rate of disease-related deaths within a given population. Screening asymptomatic individuals can increase the 5-year survival rate by detecting the disease earlier, but it may not reduce mortality if the disease progression or treatment outcomes are unaffected. Therefore, relying solely on a 5-year survival rate, or confusing it with mortality, can misrepresent the life-saving benefits of screening programs.[10 15 22 23] As evidenced in these widespread misunderstandings of fundamental statistical concepts, the lack of statistical health literacy among healthcare professionals not only impedes accurate assessment of medical interventions but also potentially compromises the overall effectiveness of evidence-based medicine. [1 5 22 24]

Although statistical literacy, like other medical knowledge and clinical skills, can affect patient health outcomes, the medical education community often overlooks the importance of continuously enhancing formal training to foster statistical literacy. To introduce improved formal training to medical students and doctors, it is imperative to assess their current statistical literacy on major clinical issues highlighted in the literature and identify areas for improvement. For a notable example, a study from Germany assessed the minimum statistical literacy of 169 final-year medical students, measuring their understanding of 10 basic statistics concepts, including sensitivity, specificity, PPV, RRR, and mortality.[2] The students' median percentage of correct answers to these questions was 50% before brief training, which increased to 90% afterward.

We aimed to assess the statistical literacy of medical students and doctors in South Korea, combining the conceptual components of the German study and adapting them to a more clinically relevant context.[2] When assessing statistical literacy, we focused on understanding four key statistical concepts: a) single-event probability, b) RRR, c) PPV, and d) 5-year survival rate. We also assessed their basic numeracy (i.e., an elementary skill to

understand and use numbers), which may be a prerequisite for statistical literacy.[5] This assessment will help identify which statistical concepts are most challenging for our target population and guide the development of improved medical education.

Methods

Study setting

Between October 2018 and January 2019, we conducted a cross-sectional survey among a convenience sample of medical students from a single medical school and doctors from its affiliated teaching hospital on the same campus in Seoul, South Korea. South Korean medical education consists of a comprehensive 6-year program. The medical school in this study admits approximately 135 students per academic year, with students completing their clinical clerkships at the medical school's affiliated teaching hospitals in their fifth and sixth years. The teaching hospital on the same campus has a capacity of 1,800 beds and serves a large patient population, handling 2.4 million outpatient visits and 560,000 inpatients each year. Medical students from all six years of the program, trainee doctors (interns and residents), and attending physicians at the hospital were eligible to participate in the study. We contacted student organizations and resident physicians to inform them about the study and sought their assistance in recruiting participants. Co-investigators, who were medical students or doctors-in-training themselves, approached potential participants before and after events, such as meetings, classes, and conferences that many students and doctors attended. They explained the study and invited individuals to participate. Participants who agreed were given a questionnaire on the spot. The entire questionnaire included two separate thematic sections: medical statistical literacy (the focus of this paper) and patient-centredness (not reported in this paper) along with key demographic information, such as gender, age, students' year of study or doctor's grade and specialty. The questionnaire took approximately 5–10 minutes to complete. Participants received a gift card worth around 4 USD as a token of appreciation.

This study was approved by the Institutional Review Board of Seoul National University

(IRB No. 1808-185-969).

Sample

We aimed to obtain a diverse sample of medical students across different years of study and doctors from various specialties within the teaching hospital. For medical students, our goal was to survey approximately one-third of students in each grade of the six-year medical school program, targeting 50 students per year for a total student sample of 300. Due to the expected challenges in surveying hospital doctors, we targeted approximately one-fourth of the trainee doctors, including both one-year interns and three- or four-year residents, as well as 100 attending physicians from a total of nearly 900. Since interns are not yet affiliated with a specialty, specialty information was collected only from residents and attending physicians. We aimed to survey residents and attending physicians from 13 specialties out of the 23 clinical specialties, which we classified into three main groups: medical (internal medicine, paediatrics, rehabilitation, family medicine, and psychiatry), surgical (emergency medicine, obstetrics and gynaecology, orthopaedics, otorhinolaryngology, and general surgery), and service (radiology, laboratory medicine, and anaesthesiology). The approximate proportion of these groups in our sample was set to 5:3:2 for residents and attending physicians, reflecting the proportion of residency openings in these specialties in 2019. See Supplementary Table 1 for the target and actual numbers of participants.

Measures

To assess basic numeracy, we used three fill-in-the-blank questions previously designed to measure basic numeracy across various populations in prior studies.[5 25] These questions involved converting between percentages and frequencies and interpreting chance outcomes. To assess statistical literacy, we developed four questions based on two previous studies regarding the statistical literacy of medical students and professionals that identified four commonly misunderstood statistical concepts: single-event probability, RRR, PPV, and 5-year survival rate.[2 5] Our research team, consisting of experts in clinical medicine and medical education, initially formulated questions to evaluate comprehension of the four

concepts based on their definitions. The question on single-event probability was included as it is often confusing due to the lack of a reference class, causing diverse misunderstandings. The RRR question aimed to assess participants' ability to explain this concept in the context of comparing new versus conventional chemotherapy. The PPV question involved calculating the probability of having breast cancer given a positive mammogram result, using information on sensitivity, specificity, and prevalence. The question on the 5-year survival rate was framed around the increased survival rates of thyroid cancer in South Korea to evaluate participants' understanding of the distinction between increased survival and reduced mortality.[5 23] The wording of the formulated questions was further refined through an iterative process involving both medical students and physicians to improve readability and real-world clinical relevance. The final set of questions was evaluated and revised until consensus was reached. See Box 1 for an English translation of the exact wording of the questions and response options.

[Insert Box 1 about here]

Statistical analysis

The collected data was converted into an anonymised database and analysed. The percentage of correct answers for each basic numeracy and statistical literacy question was computed. We analysed the percentage of correct answers for medical students and doctors for the four statistical literacy questions, examining variations by students' grades and doctors' specialty. Differences between subgroups were compared using the chi-square test for two groups and ANOVA for three groups. All statistical analyses were conducted using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA). *P*-values were based on a two-sided significance level of 0.05.

Patient and public involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study.

Results

A total of 303 medical students and 291 doctors participated in the survey. Table 1 presents the characteristics of the participants.

[Insert Table 1 about here]

The correct answer rate for all three basic numeracy questions was close to 100% in both the student and doctor groups (Figure 1). The first two statistical literacy questions—the single-event probability question and the RRR question—also had high correct answer rates, approximately 95% and 83%, respectively. However, the PPV question and the 5-year survival rate question had much lower correct answer rates, approximately 49%. There was no notable difference in correct answer rates between medical students and doctors, except for the 5-year survival rate question, where doctors had a higher correct answer rate (57.7%) than medical students (40.9%, $p < 0.001$). See Supplementary Table 2 for the distributions of answer choices selected for each statistical literacy question.

[Insert Figure 1 about here]

Figure 2 presents the percentage of correct answers given by medical students at different grade levels for statistical literacy questions. In general, the correct answer rate increased with grade level, although the observed differences were not statistically significant. For instance, 46.6% of the third- and fourth-year medical students answered the 5-year survival rate question correctly, compared to 38.0% of the premedical and first- and second-year medical students.

[Insert Figure 2 about here]

Doctors in service specialties consistently demonstrated higher correct answer rates than those in medical or surgical specialties, although these differences were not statistically significant (Figure 3). Notably, the correct answer rate for the PPV question was higher among doctors in service specialties (56.1%) compared to their peers in medical (48.8%) and surgical (47.6%) specialties. The overall mean score on the four statistical literacy questions was also slightly higher among doctors in service specialties (Supplementary Table 3).

[Insert Figure 3 about here]

Discussion

Despite their high basic numeracy, the medical students and doctors in this study demonstrated areas for improvement in key aspects of statistical literacy. While over 80% of participants correctly answered questions on single-event probability and RRR, correct answer rates were substantially lower for the PPV and 5-year survival rate questions. Both groups performed similarly on most questions, except for the 5-year survival question, where medical students had a significantly lower correct answer rate than doctors. Notably, increasing years in medical school did not result in considerably higher correct answer rates.

While this study may offer only a snapshot of the statistical literacy of Korean medical students and doctors, it serves as a window to examine the current state of medical education concerning statistical literacy in South Korea and beyond. Since the students and doctors in this study possessed high basic numeracy skills, their underdeveloped statistical literacy cannot be attributed to their basic numeracy. The two questions about statistical literacy, single-event probability and RRR, had high correct answer rates. This could be mainly because they are more closely related to basic numeracy compared to the other two questions, PPV and 5-year survival rate. These are areas where medical education can play an important role. Previous studies have linked insufficient statistical literacy in doctors to a non-transparent presentation of statistical information and to medical schools that do not give adequate attention to the importance of teaching risk communication.[2 5] Therefore, it is crucial to introduce medical education and professional development programs that enhance statistical literacy among medical students and doctors. In these programs, the main focus should be on enhancing the ability to make statistical inferences from medical test results and to acquire proficiency in using relevant medical statistics to critically evaluate the effects of illness and the life-saving advantages of medical treatments. The following discussion focuses on the two areas—PPV and 5-year survival rate, where there is a large room for

improvement, as demonstrated in this study.

Although the medical students and doctors in this study had a significantly higher accuracy rate (approximately 49%) in answering the PPV question compared to their counterparts in previous German studies (approximately 20%)[2 5], this rate is still far from satisfactory, particularly from a medical education standpoint. Our results indicated that being in higher years in medical school and even currently practicing medicine as a doctor was not associated with higher correct answer rates for the PPV question, suggesting both undergraduate and postgraduate medical education could improve significantly. Participants might have confused the PPV with sensitivity,[13] which was presented as 90% in the question. Alternatively, the tendency to overestimate PPVs, as observed in previous studies, [12 16 26 27] might have led to the incorrect answer. Regardless of which explanation is more plausible, it is important to remember that overestimating PPVs of medical tests can lead to further tests, unnecessary treatments, and potential patient harm.[5] There is ample evidence that presenting statistical information in the form of natural frequencies rather than probabilities can improve conditional probabilistic reasoning, as it helps with an intuitive understanding of conditional probabilities.[8 17 28-31] The observed effect of the natural frequency format was evident in individuals with both high and low numeracy.[29 32] Furthermore, studies have shown that teaching medical students and doctors how to translate relevant statistical information presented in probabilities into natural frequencies also facilitates conditional probabilistic reasoning.[5 28 33 34] . However, given that statistical literacy skills improved after training can deteriorate within one to two months without reinforcement, medical schools and boards should implement regular statistical training and assessments to maintain these crucial competencies.[9 35] It would be helpful to incorporate these research findings more actively when developing training programs to improve medical students' and doctors' ability to estimate the predictive values of medical tests.

Another major weak area in statistical literacy identified in this study was the confusion between 5-year survival rate and mortality. Almost half of medical students and

one-third of doctors in this study incorrectly believed that an increase in the 5-year survival rate of thyroid cancer indicates a decrease in mortality from the disease. The relatively higher correct answer rate among doctors compared to medical students is likely due to their experience in clinical practice, where the concepts of 5-year survival rates and mortality are frequently used and compared. Nevertheless, the correct answer rate was still less than 60% among doctors and even lower among medical students, which is concerning because these two concepts must be carefully distinguished when assessing the impact of illness and the life-saving benefits of medical interventions.[5 23] Otherwise, healthcare professionals may overestimate the life-saving advantages of cancer screening, which could explain the overutilisation of low-value cancer screenings and the overdiagnosis of cancer. This misunderstanding has far-reaching consequences. Indeed, the overuse of low-value cancer screenings is contributing to cancer overdiagnosis and overtreatment globally, with South Korea being a particularly notable example of this trend.[36-38] When teaching about the 5-year survival rate and mortality, it is critical to emphasise their key difference: the denominators used in their calculation. For 5-year survival rate, the denominator is the number of people diagnosed with the disease, whereas for mortality rate, it is the number of people in the general population.[23 39] Understanding this distinction is essential for correctly interpreting these statistics in medical contexts. Utilising visual aids such as bar charts or pie charts can be helpful. These graphics could separately show (i) the proportion of people who survived for five years after being diagnosed with a certain disease (5-year survival rate), and (ii) the annual rate of disease-related deaths in the population (mortality rate). Such visual representations can also facilitate comparing these rates across different populations or groups.[21]

This study has several limitations. First, we recruited participants from only a single medical school and its affiliated teaching hospital in South Korea using a convenient sampling method. This limits the generalisability of our findings beyond these specific institutions to the broader population of medical students and doctors across South Korea.

Even within the single centre, participants who chose to respond to our survey might have different statistical literacy characteristics than those who did not participate, potentially leading to an overestimation of statistical literacy if those who felt more confident in their abilities were more likely to participate. Additionally, the exact response rate could not be calculated, as the survey was conducted with a target number of participants based on the proportion of students and doctors, and data collection ended once the target was reached. Second, while our work focused on key weak areas of statistical literacy among medical students and doctors as highlighted in previous research [2 5], it must be explicitly acknowledged that the questionnaire does not comprehensively cover all aspects of statistical literacy relevant to medical practice, as one would expect from a validated instrument. Third, we did not investigate factors that may influence statistical literacy beyond examining its associations with basic characteristics available in the data.

Despite these limitations, this study provides the first assessment of the statistical literacy of Korean medical students in varying grades and doctors with varying clinical experience and specialties. Based on the findings of this study, we designed and carried out an educational intervention aimed at improving medical students' statistical literacy, that is necessary to understand medical statistics and critically assess the available scientific evidence. We believe that this study will inspire further research in improving medical education regarding statistical literacy in South Korea and other countries.

Acknowledgments: We thank the medical students and doctors who voluntarily participated in this study.

Funding: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2018R1A2B2009257). The funder was not involved in the design of the study, the collection, analysis, and interpretation of data, or in writing the submitted work.

Conflict of interest: The authors have declared that no competing interests exist.

Ethical approval: This study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1808-185-969) and informed consent was obtained from the participants.

Authors' contribution

SYL, UNK, and YKD developed the questionnaire. SYL, YS, JJY, HH, YK, and YKD contributed to data collection. SYL conducted the statistical analysis and wrote the first draft of the manuscript. SYL, Soela K, Soyun K, and YKD critically reviewed and revised earlier drafts. All authors reviewed and provided input during the revision process. YKD secured funding for this study. YKD is the guarantor of the study.

Data sharing statement

The datasets used in the current study are available from the corresponding author upon reasonable request.

Box 1. Questionnaire to assess basic numeracy and medical statistical literacy

Basic Numeracy

BN Q1. People who take drug A have a 1% chance of having an allergic reaction. If 1000 people take drug A, how many people are expected to have an allergic reaction?
Answer: _____ out of 1000 (*Correct answer: 10*)

BN Q2. 1 out of 1000 people who take drug B may have an allergic reaction. What percentage of people who take drug B are expected to have an allergic reaction?
Answer: _____ % (*Correct answer: 0.1*)

BN Q3. Suppose that a coin is tossed 1000 times. How many times do you expect to get heads out of 1000 attempts?
Answer: About _____ times out of 1000 (*Correct answer: 500*)

Statistical Literacy

SL Q1. Antidepressant C has a 20% risk of causing weight gain. Which of the following is the most correct explanation? (*Single-event probability*)
a. Patients with depression who take C have a 20% increase in weight.
b. 2 out of 10 patients with depression who take C experience weight gain. ***
c. If you take 10 pills of C, 2 of them have a risk of causing weight gain.
d. If you take C for 10 months, you are at risk of weight gain for 2 months.

SL Q2. A new chemotherapy drug reduces the risk of vomiting (as a side effect) by 60% compared to conventional chemotherapy. Which of the following is the most correct explanation? (*Relative risk reduction*)
a. When using the new chemotherapy, the risk of vomiting is reduced to 40%.
b. When using the new chemotherapy, vomiting occurs in 40 of 100 patients.
c. Among 100 patients, the number of patients experiencing vomiting is reduced by 60 when using the new chemotherapy compared to conventional chemotherapy.
d. If vomiting occurs in 50 out of 100 patients when using conventional chemotherapy, vomiting occurs in 20 out of 100 patients when using the new chemotherapy. ***

SL Q3. The prevalence of breast cancer for women in their 60s is 1%. A woman with breast cancer has a 90% chance of being positive on a mammogram, and a woman without breast cancer has a 9% chance of testing positive on a mammogram. Which of the following is the closest to the probability that a woman with a positive mammogram actually has breast cancer? (*Positive predictive value*)
a. 81%
b. 9 out of 10
c. 1 out of 10 ***
d. 1%

SL Q4. The 5-year survival rate of thyroid cancer in South Korea has improved compared to the past. Which of the following is the most correct explanation? (*5-year survival rate*)
a. It is possible that the incidence of thyroid cancer has decreased.
b. An improvement in the 5-year survival rate of thyroid cancer means an improvement in the cure rate of thyroid cancer.
c. An improvement in the 5-year survival rate of thyroid cancer means a reduction in mortality due to thyroid cancer.
d. Early detection of thyroid cancer may increase the 5-year survival rate, but may not reduce mortality. ***

Notes. *** denotes the correct answer. The questionnaire was administered in Korean; this is an English translation. Italicised words were not included in the questionnaire but are shown here for clarity.

Table 1. Characteristics of study participants

		Total (N=594)		Medical Students (n=303)		Doctors (n=291)	
		n	%	n	%	n	%
Age group							
	–19	37	6.2	37	12.2	0	0.0
	20–29	371	62.5	265	87.5	106	36.4
	30–39	140	23.6	1	0.3	139	47.8
	40–49	44	7.4	0	0.0	44	15.1
	50+	2	0.3	0	0.0	2	0.7
Gender							
	Male	355	59.8	179	59.1	176	60.5
	Female	239	40.2	124	40.9	115	39.5
Student's grade							
	Premedical			100	33.0		
	Medical			203	67.0		
Doctor's grade							
	Intern					40	13.7
	Resident					146	50.2
	Attending					105	36.1
Doctor's specialty							
	Medical					125	43.0
	Surgical					84	28.9
	Service					41	14.1
	Missing					1	0.3

Note. See the text for the classification of medical specialties.

References

1. Gigerenzer G, Gray JAM. Launching the Century of the Patient. In: Gigerenzer G, Gray JAM, eds. Better Doctors, Better Patients, Better Decisions: The MIT Press 2011:3-28.
2. Jenny MA, Keller N, Gigerenzer G. Assessing minimal medical statistical literacy using the Quick Risk Test: a prospective observational study in Germany. *BMJ open* 2018;8(8):e020847.
3. Monahan J. Statistical literacy: A prerequisite for evidence-based medicine: SAGE Publications Sage CA: Los Angeles, CA, 2007:i-ii.
4. Schmidt FM, Zottmann JM, Sailer M, et al. Statistical literacy and scientific reasoning & argumentation in physicians. *GMS Journal for Medical Education* 2021;38(4)
5. Gigerenzer G, Gaissmaier W, Kurz-Milcke E, et al. Helping doctors and patients make sense of health statistics. *Psychological science in the public interest* 2007;8(2):53-96.
6. Osborn CY. Shared decision making requires statistical literacy. *AMA Journal of Ethics* 2009;11(4):301-05.
7. Gigerenzer G. Better doctors, better patients, better decisions. 2014
8. Lakhlifi C, Lejeune F-X, Rouault M, et al. Illusion of knowledge in statistics among clinicians: evaluating the alignment between objective accuracy and subjective confidence, an online survey. *Cognitive Research: Principles and Implications* 2023;8(1):23.
9. Soto-Mota A, Maravilla EC, Fragoso JLC, et al. Evaluation of statistical illiteracy in Latin American clinicians and the piloting evaluation of a short course across multiple timepoints. *BMC Medical Education* 2022;22(1):54.
10. Gigerenzer G. Making sense of health statistics. *Bull World Health Organ* 2009;87(8):567. doi: 10.2471/blt.09.069872
11. Bramwell R, West H, Salmon P. Health professionals' and service users' interpretation of screening test results: experimental study. *BMJ* 2006;333(7562):284.
12. Casscells W, Schoenberger A, Graboys TB. Interpretation by Physicians of Clinical Laboratory Results. *New Engl J Med* 1978;299(18):999-1001.
13. Eddy DM. Probabilistic reasoning in clinical medicine: Problems and opportunities. In: Kahneman D, Slovic P, Tversky A, eds. Judgment under uncertainty: Heuristics and biases Cambridge: Cambridge University Press 1982:249-67.
14. Wegwarth O, Gigerenzer G. US gynecologists' estimates and beliefs regarding ovarian cancer screening's effectiveness 5 years after release of the PLCO evidence. *Scientific reports* 2018;8(1):17181.
15. Wegwarth O, Schwartz LM, Woloshin S, et al. Do physicians understand cancer screening statistics? A national survey of primary care physicians in the United States. *Annals of internal medicine* 2012;156(5):340-49.
16. Whiting PF, Davenport C, Jameson C, et al. How well do health professionals interpret diagnostic information? A systematic review. *BMJ Open* 2015;5(7):e008155. doi: 10.1136/bmjopen-2015-008155 [published Online First: 2015/07/30]
17. Hoffrage U, Gigerenzer G. Using natural frequencies to improve diagnostic inferences. *Acad Med* 1998;73(5):538-40.
18. Aronowitz R, Greene JA. Contingent knowledge and looping effects—a 66-year-old man with PSA-detected prostate cancer and regrets. *New Engl J Med* 2019
19. Gigerenzer G. HIV screening: helping clinicians make sense of test results to patients. *BMJ* 2013;347:f5151. doi: 10.1136/bmj.f5151 [published Online First: 2013/08/24]
20. Gigerenzer G, Hoffrage U, Ebert A. AIDS counselling for low-risk clients. *Aids Care* 1998;10(2):197-211.
21. Fagerlin A, Zikmund-Fisher BJ, Ubel PA. Helping Patients Decide: Ten Steps to Better Risk Communication. *JNCI: Journal of the National Cancer Institute* 2011;103(19):1436-43. doi: 10.1093/jnci/djr318
22. Wegwarth O, Gaissmaier W, Gigerenzer G. Deceiving numbers: survival rates and their impact on doctors' risk communication. *Med Decis Making* 2011;31(3):386-94. doi:

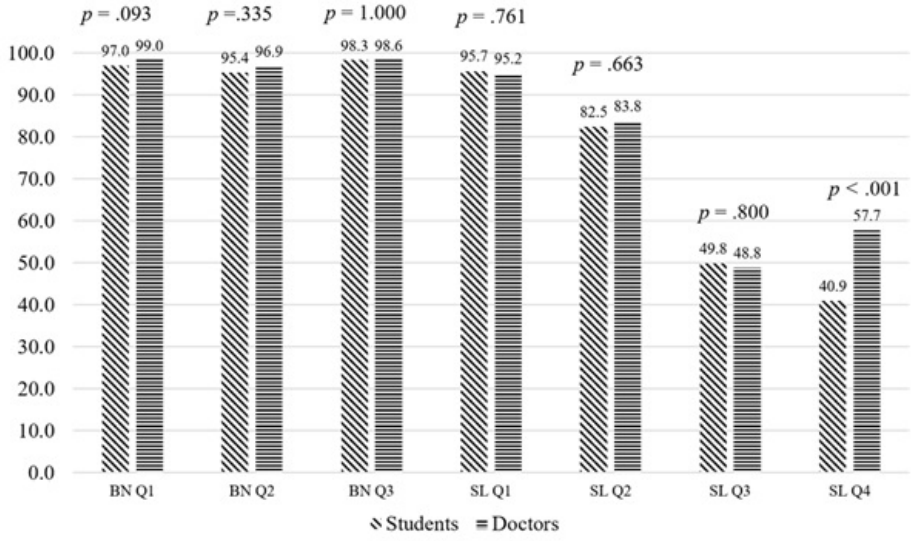
10.1177/0272989x10391469 [published Online First: 20101229]
23. Welch HG, Schwartz LM, Woloshin S. Are increasing 5-year survival rates evidence of success against cancer? *Jama* 2000;283(22):2975-78.
24. Petrova D, Mas G, Navarrete G, et al. Cancer screening risk literacy of physicians in training: An experimental study. *PLOS ONE* 2019;14(7):e0218821. doi: 10.1371/journal.pone.0218821
25. Schwartz LM, Woloshin S, Black WC, et al. The role of numeracy in understanding the benefit of screening mammography. *Annals of internal medicine* 1997;127(11):966-72.
26. Manrai AK, Bhatia G, Strymish J, et al. Medicine's uncomfortable relationship with math: calculating positive predictive value. *JAMA Intern Med* 2014;174(6):991-93.
27. Lyman GH, Balducci L. Overestimation of test effects in clinical judgment. *J Cancer Educ* 1993;8(4):297-307.
28. Feufel MA, Keller N, Kendel F, et al. Boosting for insight and/or boosting for agency? How to maximize accurate test interpretation with natural frequencies. *BMC Medical Education* 2023;23(1):75. doi: 10.1186/s12909-023-04025-6
29. Galesic M, Gigerenzer G, Straubinger N. Natural frequencies help older adults and people with low numeracy to evaluate medical screening tests. *Medical Decision Making* 2009;29(3):368-71.
30. Gigerenzer G. What are natural frequencies? *Bmj* 2011;343:d6386.
31. McDowell M, Jacobs P. Meta-analysis of the effect of natural frequencies on Bayesian reasoning. *Psychological bulletin* 2017;143(12):1273.
32. Chapman GB, Liu J. Numeracy, frequency, and Bayesian reasoning. *Judgment and Decision Making* 2009;4(1):34-40.
33. Sedlmeier P, Gigerenzer G. Teaching Bayesian reasoning in less than two hours. *J Exp Psychol Gen* 2001;130(3):380-400. doi: 10.1037//0096-3445.130.3.380
34. Kurzenhäuser S, Hoffrage U. Teaching Bayesian reasoning: an evaluation of a classroom tutorial for medical students. *Med Teach* 2002;24(5):516-21.
35. Kim S, Kim S, Choi Y-j, et al. Natural frequency tree-versus conditional probability formula-based training for medical students' estimation of screening test predictive values: a randomized controlled trial. *BMC Medical Education* 2024;24(1):1207.
36. Li M, Dal Maso L, Vaccarella S. Global trends in thyroid cancer incidence and the impact of overdiagnosis. *The Lancet Diabetes & Endocrinology* 2020;8(6):468-70.
37. Ahn HS, Kim HJ, Welch HG. Korea's thyroid-cancer "epidemic"—screening and overdiagnosis. *N Engl J Med* 2014;371(19):1765-67.
38. Lee J-H, Shin SW. Overdiagnosis and screening for thyroid cancer in Korea. *The Lancet* 2014;384(9957):1848.
39. Gigerenzer G, Wegwarth O. Five year survival rates can mislead. *BMJ: British Medical Journal (Online)* 2013;346

Figure legends

Figure 1. Correct answer rates for basic numeracy and medical statistical literacy questions
Notes. BN Q1: Converting a percent to a proportion, BN Q2: Converting a proportion to a percent, BN Q3: Familiarity with chance outcome, SL Q1: Single-event probability, SL Q2: Relative risk reduction, SL Q3: Positive predictive value, SL Q4: 5-year survival rate.

Figure 2. Correct answer rates for medical statistical literacy questions by student grade
Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate.

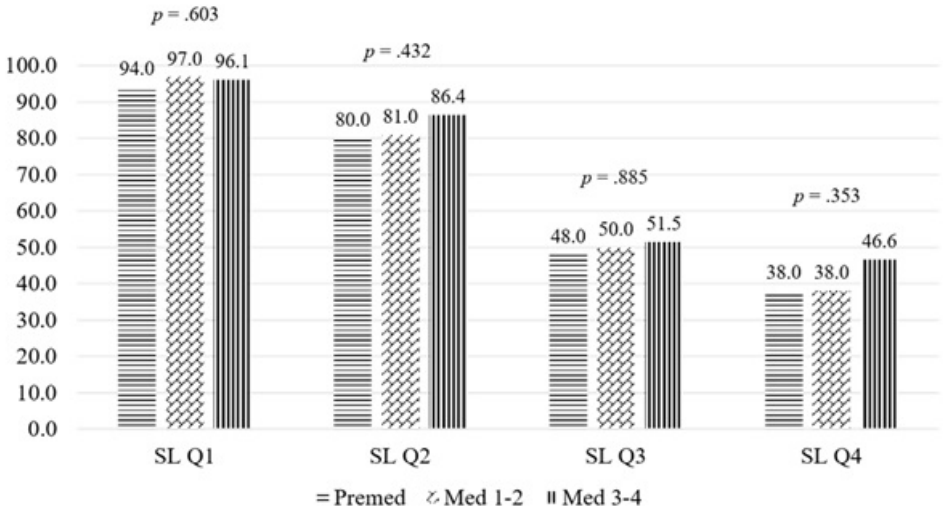
Figure 3. Correct answer rates for medical statistical literacy questions by specialty
Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate. See the text for the classification of medical specialties. Interns are not included in this analysis. The response from one attending physician who did not specify specialty was excluded from the analysis.



Notes. BN Q1: Converting a percent to a proportion, BN Q2: Converting a proportion to a percent, BN Q3: Familiarity with chance outcome, SL Q1: Single-event probability, SL Q2: Relative risk reduction, SL Q3: Positive predictive value, SL Q4: 5-year survival rate.

Correct answer rates for basic numeracy and medical statistical literacy questions

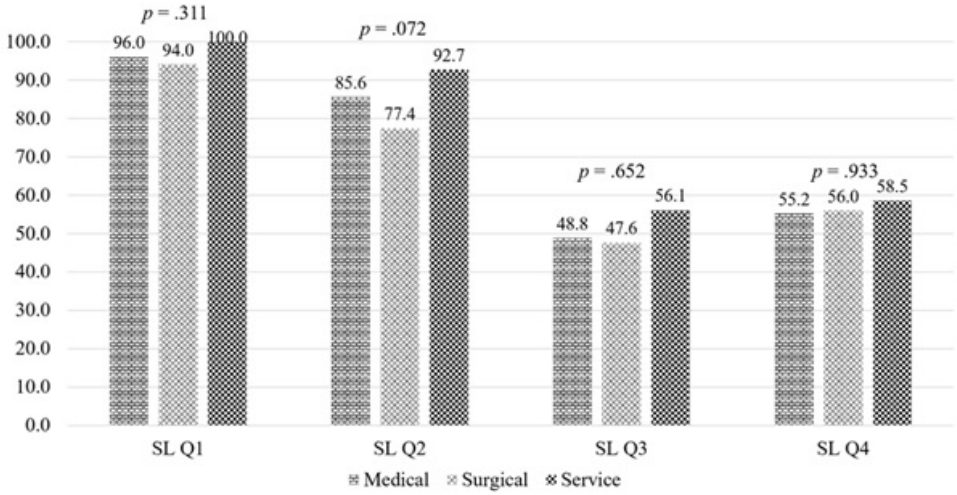
171x117mm (96 x 96 DPI)



Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate.

Correct answer rates for medical statistical literacy questions by student grade

164x103mm (96 x 96 DPI)



Notes. Q1: A single-event probability, Q2: Relative risk reduction, Q3: Positive predictive value, Q4: 5-year survival rate. See the text for the classification of medical specialties. Interns are not included in this analysis. The response from one attending physician who did not specify specialty was excluded from the analysis.

Correct answer rates for medical statistical literacy questions by specialty

164x108mm (96 x 96 DPI)

Assessing statistical literacy in medical students and doctors: a survey in South Korea

Supplementary Table 1. Target and actual numbers of participants

			Target number of participants	Actual number of participants	% of goal
Student	Premedical	1st year	50	50	100.0
		2nd year	50	50	100.0
	Medical	1st year	50	50	100.0
		2nd year	50	50	100.0
		3rd year	50	53	106.0
		4th year	50	50	100.0
	Total		300	303	101.0
Doctor	Intern	—	40	40	100.0
	Resident	Medical	68	68	100.0
		Surgical	40	51	127.5
		Service	24	26	108.3
	Attending	Medical	62	57	91.9
		Surgical	30	33	110.0
		Service	16	15	93.8
		Missing	—	1	—
	Total		280	291	103.9
Total			580	594	102.4

Note. See the text for the classification of medical specialties.

2

Supplementary Table 2. Distribution of answer choices selected to medical statistical literacy questions by medical students and doctors (%)

Choice	Single-event probability		Relative risk reduction		Positive predictive value		5-year survival rate	
	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)	Students (n=303)	Doctors (n=291)
1	1.7	2.1	5.0	4.8	11.6	15.8	1.7	0.3
2	**95.7**	**95.2**	0.3	0.0	24.8	25.1	8.3	9.6
3	2.3	2.7	12.2	11.3	**49.8**	**48.8**	49.2	32.3
4	0.3	0.0	**82.5**	**83.8**	13.5	10.0	**40.9**	**57.7**
Missing					0.3			

Notes: The correct answers are in bold.

Supplementary Table 3. Mean scores of medical statistical literacy by characteristics of study participants

		Total (N=594)			Medical Students (n=303)			Doctors (n=291)		
		n	Mean	*SD*	n	Mean	*SD*	n	Mean	*SD*
Total			2.8	0.9		2.7	0.9		2.9	1.0
Age group										
	–19	37	2.4	0.9	37	2.4	0.9			
	20–29	371	2.8	0.9	265	2.7	0.9	106	3.1	1.0
	30–39	140	2.6	0.9	1	4.0	—	139	2.6	0.9
	40–49	44	3.1	0.9				44	3.1	0.9
	50+	2	3.0	1.4				2	3.0	1.4
Gender										
	Male	355	2.9	0.9	179	2.8	0.9	176	3.0	1.0
	Female	239	2.6	0.9	124	2.5	0.9	115	2.7	0.9
Student's grade										
	Premedical				100	2.6	0.9			
	Medical				203	2.7	0.9			
Doctor's grade										
	Intern							40	2.8	1.2
	Resident							146	2.8	1.0
	Attending							105	3.0	0.8
Doctor's specialty										
	Medical							125	2.9	0.9
	Surgical							84	2.8	1.1
	Service							41	3.1	0.7
	Missing							1	4.0	—

Note. The total number of correct responses to the four medical statistical literacy questions (range: 0–4). See the text for the classification of medical specialties.