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Original Research

Statistical Literacy in Hand and Upper-Extremity Patients

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Purpose: Statistical literacy is the ability of a patient to apply basic statistical concepts to their health care. Understanding statistics is a critical component of shared decision making. The purpose of this investigation was to define levels of statistical literacy in an upper-extremity (UE) patient population. We aimed to determine if patient demographics would be associated with statistical literacy.

Methods: An electronic survey was administered to a consecutive series of UE patients at a single institution. We recorded baseline demographics, Single Assessment Numeric Evaluation scores, the Berlin Numeracy Test (BNT), and General Health Numeracy Test. We also included a surgical risk question, which asked: "Approximately 3% of patients who get carpal tunnel surgery develop an infection. If 100 patients get this surgery, how many would you expect to develop an infection?" A covariate-controlled adjusted odds ratio reflecting the association between each statistical literacy outcome measure and patient characteristics was reported.

Results: A total 254 surveys were administered, 148 of which were completed and included. Fifty percent of respondents had a high-school education or less. For the BNT, 78% scored in the bottom quartile, and 52% incorrectly answered all questions. For the General Health Numeracy Test, 34% answered 0 or 1/6 questions correctly. For the surgical risk question, 24% of respondents answered incorrectly. Respondents who had a college or graduate degree had 2.62 times greater odds (95% confidence interval, 1.09–6.32) of achieving a BNT score in a higher quartile than patients who did not have a college or graduate degree.

Conclusions: Overall levels of statistical literacy are low for UE patients.

Clinical relevance: When engaging in management discussions and shared decision making, UE surgeons should assume low levels of statistical literacy. Consideration of alternative formats, such as frequencies, video-based materials, and pictographs, may be warranted when discussing outcomes and risks of surgical procedures.

Health literacy is the ability of patients to understand basic health information and services and is an integral pillar of shared decision making.[1–6] Given this, it is important for patients to be able to understand medical evidence that is presented to them to make health care and management decisions that align with their preferences and values.[6–10] Despite the growing focus on shared decision making, recent studies estimate that 33% to 68% of the US adult population lack adequate health literacy.[7–11] For hand and upper-extremity (UE) patients, those with lower levels of health literacy tend to ask fewer questions during clinic visits and have shorter visit times.[12,13] Moreover, differing levels of health literacy may be attributable to both demographic and geographic factors.[14–16] Specific to geographic factors, there is some evidence that literacy may differ in rural as opposed to urban populations.[14–17] In addition, rural patients are often underrepresented in clinical investigations.[18]

Numeracy or statistical literacy is a component of health literacy that reflects the ability of a patient to understand and apply basic mathematical and statistical concepts related to their health care. Across a variety of medical fields, low health literacy is associated with worse health care outcomes.[11,19] However, the association between statistical literacy and health care outcomes is less well-defined.[18] Although previous investigations have aimed to define

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overall levels of health literacy for hand and UE surgery patients, a paucity of information pertaining to statistical literacy in this population exists.[2,20] Patients with limited numeracy may be susceptible to framing bias; their decision making related to their health care is more susceptible to the way in which information is presented.[4,5] Those with low levels of statistical literacy or difficulty understanding basic percentages may demonstrate substantial difficulties quantifying risk when discussing complications associated with elective UE surgery procedures.[4] An incomplete understanding of the risks and benefits of a surgical procedure serves as a barrier to obtaining informed consent.

Prior investigations have demonstrated that UE patients with low health literacy still want to be actively involved in the shared decision making process; however, these conversations may need to be individualized based on a patient's level of understanding.[21] For some patients, simply presenting percentages may make true shared decision making challenging because it it relies on a patient's ability to comprehend the evidence-based support for treatment options, including rates of clinical success and complications.[22–24] Consider the scenario of a hand surgeon discussing fixation versus closed treatment of a distal radius fracture with a patient aged <60 years. The CROSSFIRE trial, which randomized open reduction internal fixation and closed treatment, could serve as a basis for discussion.[25] As part of shared decision making, it would not be uncommon for a surgeon to state the following:

"*If we decide to treat your fracture with a cast, there is 7% chance of requiring an operation in the future and a 3% chance of requiring an additional procedure if we treat your fracture surgically.*"[25]

In this scenario, patients with lower statistical literacy may alter their decisions based on the way information pertaining to surgical risk is presented.[4,5]

The purpose of this investigation was to assess statistical literacy scores using validated measures in a UE patient population. In addition, we aimed to assess the association between patient characteristics and levels of statistical literacy. We hypothesized that statistical literacy would be low.

Materials and Methods

Institutional review board (Geisinger Health System) approval was obtained for this prospective survey study. Our sample consisted of a consecutive series of patients presenting to our outpatient UE clinics from December 2022 to January 2023. These clinics are part of a rural, integrated, academic health care system in the northeastern United States that includes a level-1 trauma center and functions as a tertiary referral center. Surveys were administered electronically via OBERD, which is a platform used to capture patient-reported outcome measures. Patients were seen by 1 of the 4 fellowship-trained hand and UE surgeons for a hand/wrist, elbow, or shoulder condition, and all surveys were completed prior to seeing the treating surgeon. Participation was voluntary, and surveys were not administered to patients aged <18 years and incarcerated patients.

The survey comprised two sections: the first collected demographic information and the second contained assessments of statistical literacy. Surveys were excluded if a valid attempt to answer all statistical literacy questions was not demonstrated and/or if technological errors occurred.

Demographic information obtained from the survey were age at appointment (years), sex ("Male," or "Female"), race ("White," or "Non-white"), if the patient was a current smoker ("Yes," or "No"), married ("Yes," or "No"), employed ("Yes," or "No"), the patient's health insurance ("Medicaid," "Medicare," "Military," or "Private"), highest level of education completed ("Graduate Degree," "Bachelors or Associates Degree," "Vocational School Diploma," "High School Diploma," "Middle or Elementary School," or "None"), and household income ("<$25,000," "$25,000–$50,000," "$50,000–$75,000," "$75,000–$100,000," ">$100,000," or "Prefer not to answer"). Also collected were the reasons for the UE appointment ("Hand/Wrist," "Shoulder," or "Elbow") as well as each patient's Single Assessment Numeric Evaluation (SANE) score, a subjective measure UE function, measured continuously from 0 to 100, where higher SANE scores indicated better patient-perceived functionality.

The second portion of the survey administered two distinct, validated measures of statistical literacy, the Berlin Numeracy Test (BNT) and the General Health Numeracy Test (GHNT-6), as well as a single contextualizing question derived by the study team. The BNT is specifically designed to test statistical numeracy in the context of risks.[24] This validated assessment has been used across a number of geographic regions and populations, including patients in a health care setting.[24] The BNT uses four questions of increasing difficulty to assess statistical literacy in terms of risk (Fig. 1). Raw scores were calculated by summing the correct responses among the 4 questions presented, thus ranging from 0 (no correct responses) to 4 (all correct responses). Stratification of raw scores into quartiles produced the overall BNT score. Patients who had a BNT score of quartile 1 ("Q1") were those who obtained a raw score of 0/4 or 1/4 and thus had the lowest level of statistical literacy. Quartiles 2 ("Q2") and 3 ("Q3") comprised patients with raw scores of 2/4 and 3/4, respectively. Finally, quartile 4 ("Q4") BNT scores represented the highest category of statistical literacy, comprising patients with raw scores of 4/4.

The GHNT-6 measures statistical literacy using six questions of varying difficulty and emphasizes probability and risk in health care scenarios (Fig. 2).[26] Statistical literacy scores for the GHNT-6 were the sum of the number of correct responses among the 6 questions total such that scores ranged from zero correct responses of 6 (0/6) to 6 correct responses of 6 (6/6), representing the lowest and highest GHNT-6 statistical literacy scores, respectively.[27]

The study team incorporated a single, nonvalidated question, referred to as the Statistical Risk Question (SRQ), into the statistical literacy testing portion of the survey. The SRQ (as follows) was separate from the BNT and GHNT-6 surveys and intended to better reflect the types of questions and conversations had between the UE surgeons and patients included in this study:

"Approximately 3% of patients who get carpal tunnel surgery develop an infection. If 100 patients get this surgery, how many would you expect to develop an infection?"

It was believed that this question would provide insights into the set of BNT and GHNT-6 responses produced by the present patient population. Scoring on the SRQ was binary in that the patient either responded correctly or did not ("Correct," or "Not correct").

Statistics

R statistical software was used to conduct a simulation study that found that 80% power was achieved and maintained for 138 simulated patients. Patient demographics and statistical literacy outcomes were summarized using frequencies and percentages, means and standard deviations, or medians and interquartile ranges, where appropriate. The unadjusted associations between each patient characteristic and the BNT and GHNT-6 statistical literacy outcomes were assessed using ordinal logistic regression models, and the unadjusted bivariate associations between patient characteristics and the odds of supplying the correct SRQ response were evaluated with binary logistic regression (33 models in total).

Berlin Numeracy Test

1. Imagine we are throwing a five-sided die 50 times. On average, out of these 50 throws how many times would this five-sided die show an odd number (1, 3, or 5)?

   _____ out of 50 throws.

2. Out of 1,000 people in a small town 500 are members of a choir. Out of these 500 members in the choir, 100 are men. Out of the 500 inhabitants that are not in the choir 300 are men. What is the probability that a randomly drawn man is a member of the choir? (Please indicate the probability in percent)

   _____%

3. Imagine we are throwing a loaded die (6 sides). The probability that the die shows a 6 is twice as high as the probability of each of the other numbers. On average, out of these 70 throws, how many times would the die show the number 6?

   _____ out of 70 throws.

4. In a forest 20% of mushrooms are red, 50% brown, and 30% white. A red mushroom is poisonous with a probability of 20%. A mushroom that is not red is poisonous with a probability of 5%. What is the probability that a poisonous mushroom in the forest is red?

   _____%

Figure 1. The BNT.

Dichotomous patient predictors that exhibited null sample sizes for one or both levels were deemed unstable predictors for the statistical literacy outcome score being modeled and removed. Also deemed unstable were any patient characteristics where the proportional odds assumption was violated. All predictors not deemed unstable during the bivariate modeling process were maintained for construction of the two multivariate ordinal logistic regression models (one for each ordinal outcome measure). A multiple binary logistic regression model was constructed to evaluate the association between all patient characteristics and SRQ. Reported from these models were the covariate-controlled adjusted odds ratio (OR) and 95% confidence interval (CI). Statistical significance at $\alpha = 0.05$ was concluded if the 95% CI did not include one.

Results

A total 254 electronic surveys were administered to eligible patients. Seventy-nine patients declined participation entirely. Two patients completed the survey twice on separate visits, and we excluded the second survey in each case. Twenty-five patients had incomplete surveys, which were also excluded. The final sample included 148 fully completed surveys.

Table 1 summarizes the demographics for all included respondents. Fifty percent of respondents had a high-school education or less and 32% reported a household income of $50,000 per year or less. Table 2 contains the responses to the BNT and GHNT-6. For the BNT, 78% scored in the bottom quartile and 52% had incorrect responses for all questions. For the GHNT-6, 34% answered zero or one of the 6 questions correctly. For the SRQ, 24% of the respondents answered incorrectly.

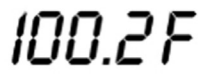
The unadjusted OR and 95% CI are reported in Appendix 1 (available online on the Journal's website at https://www.jhsgo.org). Table 3 presents the covariate-controlled adjusted OR and 95% CI. Patients who had a college or graduate degree had 2.62 times greater odds (95% CI, 1.09–6.32) of achieving a BNT score in a higher quartile than patients who did not have a college or graduate degree, given all other patient characteristics controlled for in this model were held constant. Likewise, patients who had a college or graduate degree had 5.23 times greater odds (95% CI, 2.64–10.36) of answering one more question of 6 correctly on the GHNT-6 than patients who did not have a college or graduate degree, given all other factors were held constant. No other demographic characteristics were significantly associated with improved performance on the statistical literacy assessments nor were any patient characteristics significantly associated with the odds of answering the SRQ correctly.

Discussion

In agreement with our hypothesis, overall levels of statistical literacy (as assessed by the BNT and GHNT-6) were low for a study population of hand and UE patients. Overall, 78% of patients scored in the bottom quartile of the BNT. Our observed low levels of statistical literacy are comparable with the previous assessments of overall health literacy in various health care populations.[28,29] Previous investigations have indicated that half of US adults have inadequate health literacy, which compares with our results regarding statistical literacy.[7–11,30] Menendez et al[2] assessed health literacy for patients seen by an urban hand surgery service in the United States and noted that 43% had limited health literacy as measured by the Newest Vital Sign health literacy assessment tool. Specific to statistical literacy, Carlile et al[27] administered the BNT and GHNT-6 to 198 patients presenting to a trauma clinic and found that 86% of the respondents scored in the bottom 2 quartiles. In addition, the authors found that for the GHNT-6, nearly half of patients (49%) answered 2 or fewer questions correctly.[27] This is

General Health Numeracy Test (GHNT-6)

1. Call your doctor if you have a temperature of 100.4 °F or greater. The thermometer looks like the following:



Do you call the doctor?

- Yes
- No

2. If 4 people out of 20 have a chance of getting a cold, what would be the risk of getting a cold?

_____%

3. Suppose that the maximum heart rate for a 60-year-old woman is 160 beats per minute and that she is told to exercise at 80% of her maximum heart rate. What is 80% of that woman's maximum heart rate?

_____ beats per minute

4. You ate half the container of carrots. How many grams of carbohydrates did you eat?

Nutrition Facts
Serving Size: 1 cup (85g) (3 oz.)
Servings Per Container: 2.5

Amount Per Serving	
Calories 45	Calories from Fat 0
	% Daily Value*
Total Fat 0g	0%
Saturated Fat 0g	0%
Cholesterol 0mg	0%
Sodium 55 mg	2%
Total Carbohydrate 10g	3%
Dietary Fiber 3g	12%
Sugars 5g	
Protein 1g	

_____ grams

5. Your doctor tells you that you have high cholesterol. He informs you that you have a 10% risk of having a heart attack in the next 5 years. If you start on a cholesterol-lowering drug, you can reduce your risk by 30%. What is your 5-year risk if you take the drug?

_____%

6. A mammogram is used to screen women for breast cancer. False positives are tests that incorrectly show a positive result. 85% of positive mammograms are actually false positives. If 1,000 women receive mammograms, and 200 are told there is an abnormal finding, how many women are likely to actually have breast cancer?

_____ women

Figure 2. The GHNT-6.

similar to the 56% of patients in our sample who correctly answered 2 or fewer questions. Despite geographic differences in the assessed populations (urban versus rural center), approximately 50% of patients in the series by Carlile et al[27] and our current series had a high school education or less. When engaging patients in discussion regarding management decisions, hand and UE surgeons should recognize that overall levels of statistical literacy are low. These results may be of greater importance in UE clinics where management decisions for elective and discretionary procedures are commonplace.

These data indicate that among the demographic factors studied, higher levels of education were significantly associated with higher levels of statistical literacy. This finding is similar to results noted in other reports involving populations outside of UE surgery patients. In a study by Friederichs et al,[31] the BNT was administered to a group of medical students and general practitioners. The authors found a mean BNT score of 2.3 of 4 possible correct answers, with 27% of medical students and 19% of physicians answering 4/4 questions correctly.[31] These results differ from our findings, where only 4% of our respondents answered 4/4 BNT questions correctly. Similarly, lower levels of education were associated with lower BNT scores for orthopedic trauma patients.[24] Kadakia et al[16] assessed overall health literacy in a group of 248 patients with orthopedic trauma and found that lower income levels were associated with limited health literacy. This association was also noted in a cohort of patients presenting at hand surgery clinics regarding overall health literacy.[2] Although the association between lower education levels and numeracy may seem intuitive, UE surgeons should recognize that for studied populations, approximately half of the patients will have a high-school education or less and may struggle with basic statistical concepts. This recognition should help frame shared management decisions,

Table 1
Baseline Demographics for All Included Hand and Upper-Extremity Patients

Baseline Demographics	Included Patients ($n = 148$)
Age (y), mean (SD)	55.7 (16.3)
Male sex, *n* (%)	77 (52.0)
Race, *n* (%)	
White	140 (94.5)
Black	5 (3.4)
Asian	1 (0.7)
Unknown	2 (1.4)
Highest education, *n* (%)	
None	3 (2.0)
Elementary or middle school	6 (4.1)
High-school diploma	65 (43.9)
Vocational school diploma	11 (7.4)
Associate or bachelors degree	50 (33.8)
Graduate degree or higher	13 (8.8)
Household income, *n* (%)	
$0–25,000	25 (16.9)
$25,000–50,000	23 (15.5)
$50,000–75,000	19 (12.8)
$75,000–100,000	17 (11.5)
$>100,000	26 (17.6)
Declined to answer	38 (25.7)
Health insurance, *n* (%)	
Private	89 (60.1)
Medicare	39 (26.4)
Medicaid	14 (9.5)
Military	6 (4.0)
Uninsured	0 (0.0)
Reason for appointment, *n* (%)	
Hand/wrist	83 (56.1)
Shoulder	44 (29.7)
Elbow	21 (14.2)
Currently employed, *n* (%)	76 (51.4)
Current smoker, *n* (%)	24 (16.2)
Currently married, *n* (%)	88 (59.5)
SANE score, median (IQR)	46.0 (26.0–67.0)

Table 2
Statistical Literacy Outcomes for all Included Upper-Extremity Patients

Statistical Literacy Outcomes	Included Patients ($n = 148$)
BNT scores, *n* (%)	
Quartile 1 (0/4 or 1/4 correct)	115 (77.7%)
Quartile 2 (2/4 correct)	22 (14.9%)
Quartile 3 (3/4 correct)	5 (3.4%)
Quartile 4 (4/4 correct)	6 (4.1%)
GHNT-6 scores, *n* (%)	
6 of 6 correct (highest)	16 (10.8%)
5 of 6 correct	14 (9.5%)
4/6	19 (12.8%)
3/6	17 (11.5%)
2/6	32 (21.6%)
1/6	43 (29.1%)
0/6 (lowest)	7 (4.7%)
SRQ Correct Response, *n* (%)	
Approximately 3% of patients who get carpal tunnel surgery develop an infection. If 100 patients get this surgery, how many would you expect to develop an infection?	112 (75.7%)

which should not rely solely on percentages related to risk, outcomes, and complications.

Although our SRQ is not a validated assessment of statistical literacy, it was included because we believe that a common strategy for discussing risks and benefits of surgical procedures in the setting of shared decision making includes presentations of simple percentages (eg, "The risk of infection associated with this procedure is 3%."). Previous authors have indicated that when discussing health decisions, presenting numeric estimates improves the patient's understanding of risks and unrealistic expectations.[32–34] This can be done in different ways, such as using frequencies, probabilities, or more visual methods, such as pictographs or video aids.[33,35–37] In our series, only 76% of the respondents were able to answer the following questions correctly: "*Approximately 3% of patients who get carpal tunnel surgery develop an infection. If 100 patients get this surgery, how many would you expect to develop an infection*?" In this context, nearly one-fourth of the rural hand and UE patients demonstrate difficultly comprehending and contextualizing basic statistical information. Patients with limited numeracy may be susceptible to framing bias in that their medical decision making is more susceptible to the way in which information is presented.[4,5] Alternative formats, such as frequencies with the use of a common risk denominator, video-based materials, and pictographs, can potentially be easier to comprehend and lead to a more active role in decision making.[33,35–37]

Considering our results, decision aids may be a more appropriate tool (or adjuvant aid) to help contextualize statistics and percentages. Wilkens et al[37] found that use of a decision aid for trapeziometacapral arthritis decreased decision conflict for patients. In this online decision aid, frequencies and percentages are presented descriptively (eg, "20 of the every 100 people (20%) get a stomach ache if they take an aspirin-type pill."[37] In addition, an accompanying visual figure with 100 heads exists, 20 of which are shaded red to reflect the percentage of complications that may occur.[37] Kleiss et al[38] similarly found lower levels of decision regret for patients using decision aids in their randomized, prospective study of patients with UE conditions. Decision aids from their study also used a combination of written percentages/frequencies ("2 of the 100 will have a minor wound separation [2%]") and illustrative figures for discussion of surgical risk related to carpal tunnel release.[38] Although future investigations are required in UE surgery to determine whether various methods of presenting statistical figures can alter management decisions for patients with lower levels of statistical literacy, our results suggest that conventional explanations of surgical risk stating success and complication rates as percentages may be insufficient. We agree with previous authors who have suggested that surgeons should use "universal precautions" in assuming that patients do not understand the information presented until proven otherwise.[12]

This study has a number of limitations. Inherent limitations exist to self-reported demographic data regarding accuracy. It is uncertain if patients who refused participation or incompletely filled out the survey did so because they had difficulty answering the questions. In this case, our results may overstate the levels of statistical literacy observed in UE patients. This investigation was conducted at a single, rural academic center with a homogenous patient population (95% White) that may limit the generalizability of these results. However, our reported demographics regarding education, income, and numeracy levels were similar to those from a survey study conducted at a large urban trauma center.[27] In addition, the accuracy of survey responses may be related to participant effort, even if they were willing to participate. Although our SRQ was believed to be a practical assessment, it is not a validated tool for assessing statistical literacy. Our study did not include general assessments of overall health literacy, and it is uncertain how statistical literacy contributes to overall levels of health literacy within this cohort. Future investigations are required to determine the ideal method for presenting statistics to patients with varying statistical literacy levels.

In conclusion, for our UE patient population, overall levels of statistical literacy (as assessed by the BNT and GHNT-6) were low. More than half of the patients failed to answer a single question correctly on the BNT. Higher levels of education were significantly

Table 3
Covariate-Controlled Adjusted OR (95% CI) Reflecting the Association Between Each Statistical Literacy Outcome Measure and Patient Characteristics

Patient Characteristic	Comparison	Statistical Literacy Outcome Measure, OR (95% CI)		
		BNT	GHNT-6	SRQ
Age at appointment	5-year increase	1.00 (0.99–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.01)
Sex	Male vs female	1.13 (0.49–2.58)	0.96 (0.53–1.74)	1.86 (0.79–4.37)
Race	White vs non-White	*Unstable*[†]	*Unstable*	0.99 (0.14–7.29)
Current smoker	Yes vs No	*Unstable*	0.51 (0.21–1.23)	0.37 (0.13–1.08)
Married	Yes vs No	1.55 (0.56–4.29)	1.03 (0.51–2.06)	1.27 (0.49–3.32)
Employed	Yes vs No	0.46 (0.17–1.25)	1.22 (0.60–2.45)	1.51 (0.58–3.94)
Private health insurance plan	Yes vs No	1.57 (0.56–4.43)	1.12 (0.54–2.31)	1.48 (0.55–3.94)
College or graduate degree attained	Yes vs No	2.62 (1.09–6.32)[*]	5.23 (2.64–10.36)[*]	2.18 (0.83–5.75)
Household income >$75,000	Yes vs other	2.44 (0.96–6.20)	1.72 (0.84–3.52)	0.77 (0.28–2.15)
Overall SANE score	Five-percent increase	1.00 (1.00–1.01)	1.00 (1.00–1.01)	1.00 (1.00–1.01)
Appointment reason	Hand/Wrist vs elbow	1.32 (0.34–5.17)	0.99 (0.41–2.38)	1.05 (0.31–3.54)
	Shoulder vs elbow	2.30 (0.55–9.59)	0.87 (0.33–2.28)	1.14 (0.28–4.74)

[*] Statistically significant at $\alpha = 0.05$.
[†] *Unstable*, Binary predictors for which contingency table cell counts were zero, the unadjusted ordinal logistic regression model did not converge, there existed evidence that the proportional odds assumption was violated, or some combination thereof.

associated with higher levels of statistical literacy. Nearly one-fourth of the respondents were unable to answer the following question correctly: "Approximately 3% of patients who get carpal tunnel surgery develop an infection. If 100 patients get this surgery, how many would you expect to develop an infection?" When engaging patients in management discussions and shared decision making, UE surgeons should be conscious of the low levels of statistical literacy and consider alternative formats, such as frequencies, video-based materials, and pictographs when discussing outcomes, risks, and rates of anticipated surgical complications.

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