TOPICS IN TRAINING

A National Survey of Orthopaedic Residents Identifies Deficiencies in the Understanding of Medical Statistics

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Background: Biomedical research is essential for optimizing patient care. Research has suggested inadequacies in nonorthopaedic trainees' understanding of study design and biostatistics. This study assesses orthopaedic residents' knowledge of common biostatistical and study design concepts, as well as their confidence in utilizing the medical literature.

Methods: A validated survey assessing knowledge and the application of study design concepts was administered to residents at 10 U.S. institutions. The survey tested knowledge as well as confidence and attitudes regarding common biostatistics principles. The association of demographic characteristics, work activities, and confidence and attitude ratings with test performance were examined using t tests and analysis of variance.

Results: The survey response rate was 64% (178 of 279). The largest group of participants were men (83%, 137 of 165), were between the ages of 26 and 30 years (59%, 105 of 177), and had graduated medical school within the past 4 to 10 years (43%, 76 of 175). Fifty-three percent (93 of 176) had prior biostatistics training, while 44% (77 of 176) had prior epidemiology training. Less than 5% of biostatistics or epidemiology training had taken place after medical school. Forty-seven percent (83 of 176) were unable to determine a study's design. Thirty-eight percent (67 of 178) could not apply the concept of specificity and sensitivity. Eighty-three percent (147 of 178) could not assess the strength of a relationship using odds ratios. Sixty-nine percent (123 of 178) understood the implications of p values. Previous biostatistics training, but not epidemiology or evidence-based medicine training; inclusion of reading research, attending conferences, and data analysis; as well as a self-reported finding of statistics as important for the analysis of one's own research data were significantly associated with better test performance ($p < 0.05$).

Conclusions: Notable deficits exist in orthopaedic residents' biostatistical knowledge. Greater emphasis is needed to improve biostatistics and research design training. The impact of biostatistics knowledge and/or aptitude on clinical decision-making is an area of suggested research.

Research and statistics are essential for optimizing patient care through the production and consumption of sound research. The current literature suggests inadequacies in nonorthopaedic trainees' understanding of the science of research and statistics because of poor development, maintenance, and monitoring of

these skills¹⁻¹¹. It has been reported that 30% to 90% of the medical literature contains erroneous application and interpretation of statistical methods^{6,7,12}. As the reliance on and requirement for evidence-based medicine (EBM) continues to grow, it is crucial that physicians are confident and competent in their

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abilities to evaluate and utilize medical literature. Physician knowledge and attitudes regarding statistics and research design have been assessed since the 1980s. An assessment of internal medicine faculty and residents found that only 40% of participants were able to use p values in data interpretation⁸. Recent research has identified the variables of self-reported reading of the materials and methods sections of research articles and a Western medical education as being associated with improved statistical and epidemiological knowledge^{1,5,7,9,13,14}.

In 2007, Windish et al. published the most extensive study on biostatistics and research design knowledge among medical providers⁵. After a review of 239 original articles from 6 major journals, the most commonly encountered statistical concepts and methods were tested with 277 internal medicine residents, with an average correct response score of 41%. Fifty-eight percent of residents understood the implication of p values, and 37% were able to interpret adjusted odds ratios. Only 38% of respondents were confident in assessing the correctness of a study's chosen statistical test, and 77% indicated an interest to learn more about statistics. Since that study was published, similar studies from other medical specialties (including obstetrics and gynecology and emergency medicine) have recognized the need to improve competence regarding research design and biostatistics^{3,4,9,10,13,14}.

To our knowledge, there are no studies that assess knowledge of statistics and research design among orthopaedic trainees. The purpose of the present study was to assess orthopaedic residents' knowledge of common biostatistics and research design concepts. We hypothesized that orthopaedic surgery residents would display a poor knowledge base regarding research design and analysis, but a positive interest in learning more about biostatistics and research design.

Materials and Methods

Study Participants and Survey Distribution

A network of collaborators from several U.S. institutions (L.R.L., J.C.P., A.R., S.E.A., P.O., P.J.D., and B.A.P.) invited orthopaedic surgery residency program directors to participate in this study. The 10 participating residency programs varied in size; the smallest program size was 14 residents and the largest was 60 residents. The participating programs were regionally diverse, although there were no responses from programs on the West Coast. The programs were required to print out the surveys and administer them to their residents with a maximum test completion time of 30 minutes. After completion, participating programs mailed the completed questionnaires to 1 institution for analysis.

The survey was a modification of the Biostatistical Knowledge Test Survey Instrument by Windish et al.⁵, which was originally designed for internal medicine residents. The survey consisted of 2 parts: (1) demographics and attitudes toward biostatistics and (2) biostatistics and research design knowledge. Modifications were made to questions about demographics and journal preferences (i.e., orthopaedic journals rather than internal medicine journals). Two questions assessing common activities of daily work and a resident's need for knowledge of statistics were added to the survey¹⁴. The biostatistics and

TABLE I Summary of Participant Demographics and Previous Training*

Factor	Result (N = 178)
Age category (no. [%])	
21-25 years	3 (1.69%)
26-30 years	105 (59.32%)
31-35 years	63 (35.59%)
≥36 years	6 (3.39%)
Sex (no. [%])	
Male	137 (83%)
Female	28 (17%)
Current training level (no.)	
PGY-1 (intern)	34/170 (20%)
PGY-2	38/170 (22.4%)
PGY-3	31/170 (18.2%)
PGY-4	41/170 (24.1%)
PGY-5	26/170 (15.3%)
PGY-6, PGY-7, chief, fellowship/scholar	0 (0%)
Training outside United States (no. [%])	
Yes	8 (4.71%)
College	3 (37.5%)
Medical school	5 (62.5%)
Residency	0 (0%)
Other	0 (0%)
No	162 (95.29%)
Advanced degrees (no. [%])	
MD	174 (95.1%)
DO	3 (1.64%)
PhD	1 (0.55%)
MPH or MHS	1 (0.55%)
MSc	2 (1.09%)
Training in epidemiology (no. [%])	
Yes	77 (43.75%)
College	28 (36.4%)
Medical school	57 (74%)
Residency	0 (0%)
Other	1 (1.3%)
No	99 (56.25%)
Training in biostatistics (no. [%])	
Yes	93 (52.8%)
College	49 (52.7%)
Medical school	47 (50.5%)
Residency	3 (3.2%)
Other	2 (2.2%)
No	83 (47.2%)
Training in evidence-based medicine (no. [%])	
Yes	147 (82.6%)
College	18 (12.2%)
Medical school	132 (89.8%)
Residency	27 (18.4%)
Other	0 (0%)
No	31 (17.4%)

*Incomplete denominators are due to nonresponses. PGY = postgraduate year.

TABLE II Resident Work Activities and Self-Reported Importance of Probability and Statistics Knowledge for Reported Work Activities

	No. (%)
Current work includes:	
Clinical contact	170/178 (95.5%)
Assessing guidelines and evidence summaries	147/178 (82.6%)
Explaining levels of risk to patients	160/178 (89.9%)
Assessing marketing/advertising materials	70/178 (39.3%)
Interpreting screening tests	135/178 (75.8%)
Reading research publications	160/178 (89.9%)
Attending professional conferences	152/178 (85.4%)
Exploring nontraditional treatments/management	133/178 (74.7%)
Analyzing data from own research	137/178 (77.0%)
Understanding of probability and statistics important for above-identified current work:	
Clinical contact	116/178 (65.2%)
Assessing guidelines and evidence summaries	124/178 (69.7%)
Explaining levels of risk to patients	145/178 (81.5%)
Assessing marketing/advertising materials	80/178 (44.9%)
Interpreting screening tests	109/178 (61.2%)
Reading research publications	148/178 (83.2%)
Attending professional conferences	111/178 (62.4%)
Exploring nontraditional treatments/management	120/178 (67.4%)
Analyzing data from own research	126/178 (70.8%)

research design knowledge portion of the test, which was not modified, is a 16-item test with a total of 20 questions assessing knowledge of concepts such as study design type, the understanding and application of p values, confidence intervals, survival analyses, and odds ratios. The attitude and confidence scores assessed the participants' subjective opinions about the importance of and their abilities to appropriately use biostatistics.

Data Analysis

An a priori power analysis using findings from Windish et al. was performed with G*Power software (version 3.1.9.4; Heinrich

Heine Universität Düsseldorf). Standard deviations (SDs) were computed from the reported 95% confidence intervals. In order to detect a 5% difference in the mean biostatistics knowledge score (part 2 of the questionnaire) with an estimated standard deviation of 15, a minimum sample size of 286 total participants was required to achieve 80% power at an alpha level (type-I error, 2-tailed test) that was set at 0.05⁵.

Pearson correlation coefficients, t tests, and analysis of variance were used to compare the biostatistical knowledge test score and demographic characteristics, as well as attitudes about and confidence in research activities. P values of ≤ 0.05 (2-sided) were considered significant.

TABLE III Summary of Participant Attitudes and Confidence Regarding Biostatistics and Research Design

Question Type	Average Rating
Attitude questions (1 = strongly disagree, 5 = strongly agree)	
Learn more about biostatistics given the chance	3.50
Understand most statistical terms encountered in journals	2.97
Do not trust statistics because they are easy to lie with	2.59
Often use statistics in decisions and opinions	3.73
Necessary to know something about statistics to be an intelligent reader of literature	4.46
Confidence questions (1 = none, 5 = complete confidence)	
Interpreting p value for a result	4.21
Interpreting the result of a statistical method	3.25
Assessing correct use of a statistics procedure for research question	2.56
Identifying factors that influence study power	3.13

TABLE IV Test Performance by Question*

Overall test score (%)	
Mean	49.4
Minimum	10
Maximum	90
Question (% correct [no./])	
1a (data types)	57.06% (101/177)
1b (data types)	47.46% (84/177)
1c (data types)	29.38% (52/177)
2 (study design)	52.84% (93/176)
3 (study design)	79.66% (141/177)
4a (statistics tests)	69.66% (124/178)
4b (statistics tests)	40.68% (72/177)
4c (statistics tests)	78.53% (139/177)
5 (error)	47.19% (84/178)
6 (p values)	69.10% (123/178)
7 (statistics tests)	16.85% (30/178)
8 (central tendency)	60.11% (107/178)
9 (confidence intervals)	11.80% (21/178)
10 (power)	50.56% (90/178)
11 (sensitivity/specificity)	62.36% (111/178)
12 (odds ratios)	62.36% (111/178)
13 (multivariable analysis)	40.45% (72/178)
14 (relative risk)	87.64% (156/178)
15 (strength of association)	17.42% (31/178)
16 (survival analysis)	10.17% (18/177)

*Bolded questions had <50% correct response rate.

Results

Participant Characteristics

The overall resident survey completion rate was 64% (178 of 279). Participants were mostly men (83%, 137 of 165) and were between the ages of 26 and 30 years (59%, 105 of 177). A large portion of the participants had graduated medical school within the past 4 to 10 years (43%, 76 of 175). There was good representation across all levels of training. The majority of respondents were from the South (52%, 92 of 177), followed by the Midwest (32%, 56 of 177) and the East (16%, 29 of 177). Seven non-MD advanced degrees were reported.

Slightly over half of the respondents (53%, 93 of 176) had prior biostatistics training, while 44% (77 of 176) had prior epidemiology training. "Training" in this survey was defined as ever having taken a course in the subject of interest, such as in college, medical school, residency, or graduate school. Less than 5% of biostatistics or epidemiology training had taken place after medical school. The majority of residents had training in EBM (83%, 147 of 178). A greater proportion of post-medical school training was observed for EBM (18%, 27 of 147) as compared with post-medical school training for biostatistics or epidemiology. These findings are summarized in Table I.

The top 3 work activities were clinical contact (96%, 170 of 178), explaining level of risk to patients (90%, 160 of 178),

and reading research publications (90%, 160 of 178). Of the work activities, the majority of residents believed an understanding of probability and statistics was important for explaining level of risk to patients (81%, 145 of 178) and reading research publications (83%, 148 of 178), while <80% found probability and statistics important for clinical contact (65%, 116 of 178), assessing clinical guidelines and evidence summaries (70%, 124 of 178), assessing marketing and advertising materials (45%, 80 of 178), interpreting screening tests (61%, 109 of 178), attending conferences (62%, 111 of 178), using research to explore non-standard treatments (67%, 120 of 178), and analyzing numerical data from one's own research (71%, 126 of 178). These findings are summarized in Table II.

Attitudes and Confidence

The mean attitude score was 17.3 (maximum possible score, 25; SD = 2.2). Ninety-four percent (167 of 177) of respondents "agreed" or "strongly agreed" that some statistics knowledge is necessary to be an "intelligent reader" of medical literature. Slightly over one-quarter of residents agreed that they can

TABLE V Impact of Selected Demographic Factors on Test Performance*

Factor	Mean Test Score $\pm$ SD	P Value
Sex		0.34
Male	50.29 $\pm$ 12.06	
Female	47.5 $\pm$ 14.54	
Age in years		0.24
21-25	60.00 $\pm$ 26.46	
26-30	48.57 $\pm$ 13.98	
31-35	51.03 $\pm$ 14.23	
≥ 36	42.5 $\pm$ 12.94	
Residency program size		0.06
<20	42.73 $\pm$ 20.10	
20-30	50.82 $\pm$ 11.35	
>30	49.77 $\pm$ 15.23	
Previous epidemiology training		0.89
Yes	49.18 $\pm$ 14.35	
No	49.64 $\pm$ 14.18	
Previous biostatistics training		0.029
Yes	51.94 $\pm$ 13.15	
No	47.35 $\pm$ 14.49	
Regularly read journals		0.34
Yes	49.70 $\pm$ 14.44	
No	45.45 $\pm$ 10.83	
Residency year		0.92
Intern/PGY-1	51.03 $\pm$ 16.41	
PGY-2	48.82 $\pm$ 13.38	
PGY-3	48.39 $\pm$ 15.57	
PGY-4	49.63 $\pm$ 13.15	
PGY-5	51.15 $\pm$ 14.58	

*Boldface indicates significance. SD = standard deviation, and PGY = postgraduate year.

TABLE VI Impact of Work Activities and Usefulness of Probability and Statistics (for Work Activities) on Performance*

	Category	Mean Test Score and SD	P Value
Work activity			
Clinical contact	Yes	49.88 ± 14.23	0.0552
	No	40.0 ± 12.25	
Assessing guidelines and evidence summaries	Yes	49.8 ± 14.26	0.4677
	No	47.74 ± 14.47	
Explaining levels of risk	Yes	49.28 ± 14.16	0.6628
	No	50.83 ± 15.46	
Assessing marketing/advertising materials	Yes	51.93 ± 14.90	0.0605
	No	47.82 ± 13.65	
Interpreting screening tests	Yes	50.22 ± 14.61	0.1945
	No	46.98 ± 12.96	
Reading research publications	Yes	50.28 ± 14.22	0.0183
	No	41.94 ± 12.62	
Attending professional conferences for development	Yes	50.53 ± 14.27	0.0134
	No	43.08 ± 12.66	
Exploring nontraditional treatments/management	Yes	50.38 ± 14.31	0.1319
	No	46.67 ± 13.9	
Analyzing data from own research	Yes	50.69 ± 14.03	0.0314
	No	45.24 ± 14.40	
Are probability and statistics useful for the following work activities?			
Clinical contact	Yes	49.96 ± 13.36	0.5084
	No	48.47 ± 15.88	
Assessing guidelines and evidence summaries	Yes	49.56 ± 13.97	0.8674
	No	49.17 ± 15.03	
Explaining levels of risk	Yes	49.83 ± 13.70	0.4466
	No	47.73 ± 16.63	
Assessing marketing/advertising materials	Yes	50.75 ± 14.97	0.2687
	No	48.37 ± 13.64	
Interpreting screening tests	Yes	59.28 ± 14.27	0.3268
	No	48.12 ± 14.24	
Reading research publications	Yes	50.10 ± 14.64	0.1689
	No	46.17 ± 11.87	
Attending professional conferences for development	Yes	51.04 ± 13.50	0.0541
	No	46.79 ± 15.17	
Exploring nontraditional treatments/management	Yes	50.71 ± 13.59	0.0874
	No	46.81 ± 15.35	
Analyzing data from own research	Yes	50.87 ± 13.76	0.0363
	No	45.96 ± 14.98	

*Boldface indicates significance. SD = standard deviation.

understand all of the statistical terms that they encounter in medical journals (29%, 51 of 177, “agree” or “strongly agree”). The majority were neutral or disagreed about not trusting statistics because they are easy to lie with (88%, 156 of 177); the majority also “agreed” or “strongly agreed” (51%, 91 of 177) that given the chance, they would like to learn more about biostatistics. These findings are summarized in Table III.

The mean confidence score was 13.2 (maximum possible score, 20; SD = 2.5). Eighty-one percent (143 of 177) of

residents expressed “a lot of” or “complete” confidence in interpreting p values. Thirty-four percent (61 of 177) of participants felt confident (“a lot of” and “complete” confidence) in interpreting the results of statistical methods encountered in the literature. Approximately half (53%, 93 of 177) expressed “no confidence” or “a little confidence” in assessing the correctness of a statistical test/procedure for a research question. Fifty percent (89 of 177) expressed “neutral confidence,” while 20% (35 of 177) expressed “a little confidence”

or “no confidence” in identifying factors that influence a study's power.

Biostatistics and Research Design Knowledge Test Performance

The mean test score was 49.4 (SD, 14.3). Table IV summarizes performance by test question and concept tested. Over 35% were unable to determine a study's design (47%, 83 of 176) or apply the concept of specificity and sensitivity (38%, 67 of 178). Eighty-three percent (147 of 178) could not utilize odds ratios in determining the strength of association between 2 variables. While 81% reported “a lot of” or “complete” confidence in interpreting p values, only 69% (123 of 178) correctly answered a question about p values.

Impact of Demographics, Confidence, and Work Activities on Test Performance

The factors that were significantly associated with higher test performance included previous biostatistics training, but not epidemiology or EBM training; inclusion of reading research, attending conferences for personal development, analyzing research data in resident work activities; and a self-reported finding of probability and statistics as important for the analysis of one's own research data. These results are presented in Tables V and VI. In addition, total confidence scores demonstrated a weak but significant positive correlation (Pearson $r = 0.2$, $p = 0.007$) with test performance. No other variables were found to be significantly associated with performance on the biostatistics knowledge test.

Discussion

Competence in biostatistics and research design is essential for conducting research as well as for utilizing published research in clinical practice. The Accreditation Council for Graduate Medical Education (ACGME) requires a graduating resident to demonstrate the ability to “appraise and assimilate scientific evidence.”¹⁵ Patient care relies on EBM, and the peer review process in medical journals provides its foundation. However, the medical literature frequently has publications with methodological and statistical flaws^{6,7,12}. This requires readers to have study design and statistical knowledge competence. The findings from the present study involving orthopaedic residents is consistent with previous research in other medical specialties, with the majority of participants self-reporting low confidence in critiquing or understanding the statistics that they find in the medical literature¹⁻⁴. In their study of 281 subjects, Berwick et al. concluded that participants often drew conclusions that were unsupported by the available data when they were administered a Statistical Skills Self-Assessment Questionnaire¹. In a study of trainees and physicians at the Mayo Clinic, only 18% reported adequacy of their training in biostatistics for their needs, while 21% reported an effective teaching approach in their biostatistics coursework². Similarly, a study of Canadian obstetrics and gynecology residents revealed that 77% of residents felt little/no confidence in interpreting research statistics, with 84% being interested in additional training in

epidemiology³. Summing these findings together over the span of >30 years, the primary audience for the medical literature continues to struggle with understanding the literature. The consistency of the findings across several specialties over several decades suggests that ACGME requirements and training programs' ability to educate doctors-in-training need improvement.

Previous studies have identified some factors that consistently associate with superior biostatistics and research design knowledge. These factors may provide reasonable targets for addressing the knowledge deficiency. Previous coursework in epidemiology or biostatistics was associated with greater confidence in assimilating and critically appraising the medical literature and in designing a research study^{2,3,5,8}. Our study supports this finding (knowledge score of 51% for biostatistics or epidemiology training versus 47% for no training, $p = 0.03$). Of note, we separated biostatistics training from epidemiology or EBM training, while prior studies have combined these 3 components into 1 question. Training in one of these domains was defined as having taken a course in biostatistics, epidemiology, or EBM in college, medical school, residency, or graduate school. We found that neither epidemiology nor EBM training was associated with better performance on the knowledge test, perhaps indicating the value of numerical coursework in the development of statistics and research competence.

In addition to a history of biostatistics training, the location and timing of training also may have importance. Most studies report that the majority of biostatistics training occurs prior to residency, without continued reinforcement^{5,16}. West and Ficalora found that the higher the level of the most recent biostatistics or epidemiology training, the better the performance on biostatistics aptitude tests². In our study, we found that <5% of biostatistics or epidemiology training took place after medical school. This suggests the need for the introduction of biostatistics and research design training during residency. However, this is only achievable if program leadership recognizes the important of such training to residents' future work. In their study of medical students, internal medicine residents, and faculty, West and Ficalora reported that 87% of participants believed that knowledge of biostatistics is important for clinicians who are involved in research, while 49% believed that biostatistics knowledge is important for nonresearch clinicians—perhaps reflecting the view of biostatistics or epidemiology training as nonessential to clinical practice². This represents a barrier to the introduction of such proposed changes in graduate medical education. Nonetheless, over the past 3 decades⁵, several attempts have been made to improve post-medical school biostatistics knowledge and training^{6,12}. These range from increasing requirements from accreditation bodies—such as mandated research blocks and/or publication requirements—to increased coverage of statistical concepts for continuing medical education (CME) points in various medical journals^{5,9,12,15,17-19}.

Besides examining didactic exposure to biostatistics and research design concepts, our research examined certain work

activities that have previously been associated with superior biostatistics knowledge. We found that reading research articles, attending research conferences, and performing data analysis for one's own research were all associated with better performance on the knowledge test^{5,7}. While these activities are becoming essential components of many residency programs¹⁹, mandating these as concrete requirements throughout residency can be expected to improve the biostatistical competence of future providers. This should be followed by increased testing and reporting of common statistical concepts on all residency in-training and licensing examinations, including the Orthopaedic In-Training Examination (OITE) and the American Board of Orthopaedic Surgery (ABOS) certifying examinations. Questions testing biostatistical knowledge are both appropriate and necessary to be included in these "high-stakes" examinations. Residents will be more likely to consider biostatistics as an important aspect of their education when these concepts are repeatedly tested over the course of residency and during medical knowledge testing to become a board-certified surgeon. Currently, both the OITE and ABOS examinations do not provide detailed data on biostatistical knowledge performance.

Program size was not found to have significant impact on biostatistical knowledge survey test performance, but residents in midsize and larger programs outperformed those in smaller programs (43% versus 51% [midsize] and 50% [larger], $p = 0.06$), with the reported p value suggesting an important effect. Presumably, larger programs have greater research capacity and more extensive resources for their residents. The fundamental need for training residents to critically analyze the literature in order to provide evidence-based care suggests that notable changes in the current education process are needed. It may be beneficial for specialty organizations to consider creating a uniform biostatistical knowledge curriculum that would be available for all residents in their specialty. This would not only emphasize the importance of this topic but would assist programs that do not have the resources or the expertise to teach residents these skills.

Because our study also shows a correlation between confidence scores and test performance (Pearson $r = 0.2$, $p = 0.007$), the addition of confidence questions to in-training and board examinations may be useful in assessing future physicians' preparedness for utilization of the medical literature. This also may assist with modification of curricula as more data are gathered on physician confidence. Resources are readily available to evaluate a medical researcher's mastery of biostatistics to ensure that clinical graduates have attained the intended competencies set forth in their program's core requirements. Enders provided a thorough review of the available evaluation tools⁶.

The results of this study should be interpreted in light of several limitations. The number of study participants fell short

of the desired sample size (i.e., 286 participants). The implications of this are an increased probability of a type-II error and the failure to detect associations as significant. Additionally, the study participants were from a convenience sample of residency programs, thereby limiting the generalizability of the results. Furthermore, of the participating programs, the proportion of residents who completed the survey was 64% overall. To the extent that the participants were more (or less) interested and/or experienced with research methodology compared with nonparticipants, the results may be an overestimate or an underestimate of true knowledge and attitudes.

Conclusions

The ability to critically read the medical literature is needed to provide the highest value and outcomes in clinical care. This study identified notable gaps in orthopaedic residents' biostatistical knowledge and understanding of study design. These findings are consistent with findings from other specialties and highlight the need for curriculum changes (including the continued representation of research and biostatistics questions on in-training examinations, the requirement for resident involvement in analysis in data from their research projects, and the requirement for resident attendance at research conferences) because similar deficits have remained across 3 decades of resident testing. ■

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