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Perceived clinical relevance and retention of basic sciences across the medical education continuum

Malau-Aduli BS, Alele FO, Heggarty P, Teague PA, Sen Gupta T, Hays R. Perceived clinical relevance and retention of basic sciences across the medical education continuum. Adv Physiol Educ 43: 293–299, 2019; doi:10.1152/advan.00012.2019.—Medical programs are under pressure to maintain currency with scientific and technical advances, as well as prepare graduates for clinical work and a wide range of postgraduate careers. The value of the basic sciences in primary medical education was assessed by exploring the perceived clinical relevance and test performance trends among medical students, interns, residents, and experienced clinicians. A pilot study conducted in 2014 involved administration of a voluntary 60-item multiple-choice question test to 225 medical students and 4 interns. These participants and 26 teaching clinicians rated the items for clinical relevance. In 2016, a similarly constructed test (main study) was made a mandatory formative assessment, attempted by 563 students in years 2, 4, and 6 and by 120 commencing general practice residents. Test scores, performance trends, clinical relevance ratings, and correlations were assessed using relevant parametric and nonparametric tests. Rank order and pass-fail decisions were also reviewed. The mean test scores were 57% (SD 7.1) and 52% (SD 6.1) for the pilot and main studies, respectively. Highest scores were observed in pathology and social sciences. Overall performance increased with increasing year of study. Test scores were positively correlated with perceived relevance. There were moderate correlations (r = 0.50–0.63; P < 0.001) between participants’ scores in the basic science and summative exams. Assessments may be key to fostering relevance and integration of the basic sciences. Benchmarking knowledge retention and result comparisons across topics are useful in program evaluation.

INTRODUCTION

The term “basic sciences” is used to include a range of initially biomedical, but recently also behavioral and social, sciences that provide the foundations of learning for medical practice (9). However, their role in learning about clinical practice has been debated frequently (10, 17, 27, 33). Curriculums grapple with requirements to maintain currency with scientific and technical advances and prepare graduates for clinical work in a wide range of careers, all within existing or even shorter time frames. This has resulted in complaints about reductions in the breadth and depth of teaching in anatomy, pathology, research skills, and even clinical experience (11, 26).

While more integrated and self-directed curriculum approaches appear to promote long-term retention of basic science knowledge, logical reasoning, and critical appraisal (9, 17, 27), scientists are concerned that retention of basic science concepts weakens beyond the early years of medical programs, with clinicians rarely using basic sciences in clinical practice (8, 10, 14, 34, 40, 44). This may be because ~50–60% of any unrehearsed knowledge is lost after 2 yr and decreases further over time, when graduates are in specialty training and clinical practice (6, 7).

In contrast, expert clinicians have been shown to use basic science principles and mechanisms to solve complex and atypical medical problems (30, 32, 35). Basic science knowledge can aid fact recall, and understanding of causal mechanisms of disease enhances accuracy of diagnostic formulation (46, 48). Additionally, this knowledge provides a coherent conceptual framework to which diagnostic information is added to improve understanding of disease mechanisms, which may help students remember or reconstruct the features of a disease (47). Understanding of basic sciences is a precondition for the understanding of clinical medicine and maximizing initial learning (28).

During medical education, poor integration of basic sciences with clinical practice may undermine the relevance of these subjects (16). Perceived irrelevance to clinical practice impedes knowledge retention and application (13, 17, 20, 38). Basic science knowledge may be regarded by some students only as hurdles to progress into the clinical years (1, 22). Students’ perceived and actual knowledge are determined by the educational strategies employed in transferring knowledge (37). Therefore, to foster learning and knowledge retention, the pedagogical and assessment strategies used for basic sciences have to go beyond “read and recapitulate” (31).

This paper reports on a project that explored how to modify the teaching-learning methodology to aid retention of basic science knowledge in a primary medical qualification program. We assessed both basic science knowledge and the perceived relevance to clinical practice of that knowledge to medical students, interns, postgraduate specialty trainees, and experienced clinicians. For the purposes of this study, clinical relevance was defined as the practical applicability of the basic science test item to the clinical setting. The main study was conducted in 2016 and built on results of a pilot study, which was conducted during 2014. Both studies are reported in this paper.
METHODS

Ethics approval was obtained from the James Cook University (JCU) Human Research Ethics Committee, and the protocol was consistent with the Declaration of Helsinki.

Study Context

The JCU College of Medicine and Dentistry provides a 6-yr medical program with a vertically and horizontally integrated, outcomes-based medical curriculum that includes substantial early exposure to clinical practice through interactions with simulated and genuine patients in a range of health care settings. The first 3 yr of the program are predominantly “preclinical,” years 4 and 5 are clinical, and year 6 is a clinically immersed “preinternship” year. In years 1–3, contact hours are a blend of lectures and case-based, small-group work, emphasizing the clinical relevance and application of knowledge. Basic science subjects are explicitly taught and assessed in the preclinical years (years 1–3), with only few revision opportunities (anatomy and acid-base revision sessions) provided in year 4.

Test Construction

All multiple-choice questions (MCQs) were accessed from the International Databases for Enhanced Assessments and Learning assessment item bank (36) and blueprinted against the basic science components of the curriculum. A total of 60 questions were selected for each test, 10 questions for each of 6 basic science disciplines (social sciences, anatomy, physiology, pharmacology, pathology, and biochemistry). All questions had brief clinical stems, with a single best answer, and 90 min were allowed to complete each test. Different sets of test questions were administered to participants in both studies (pilot and main) to ensure that students’ performances were not biased by recall of previously used test items. However, both tests were blueprinted against similar curriculum domains, and they were designed to test content material that students had learned in year 2.

Pilot Study

In 2014, all medical students, local recent JCU graduates in their first postgraduate (intern) year, were invited to take the test in a controlled environment. In addition, participants rated each question on a Likert scale of 1–5 (with 1 = highly irrelevant and 5 = highly relevant) for perceived relevance to clinical practice. Senior clinicians associated with teaching also participated in the relevance rating procedure. Five open-ended questions were included to explore the students’ and clinicians’ perceptions of the difficulty and clinical relevance of the test questions, coverage of breadth of knowledge, and their perceptions of the value of the Basic Science Retention Examination (BSRE) in relation to the medical course.

Main Study

This study built on the results of the pilot study conducted during 2014, which showed that knowledge of basic sciences increased over years 1–4 and then leveled off for year 5–6 and into the intern year. A question generated by the pilot was: Can improved assessment strengthen learning of the basic sciences and their application to clinical practice? During 2016, we administered a mandatory but formative test of basic science knowledge (BSRE) to medical students and clinicians, participating in the survey and providing responses to all of the open-ended questions, which were thematically analyzed. The analysis of the qualitative data showed that students, interns, and clinicians had similar opinions about the
Table 1. Clinical relevance rating of the BSRE disciplines

|                      | Irrelevant |            | Moderately Relevant |            | Highly Relevant |            |
|----------------------|------------|------------|---------------------|------------|-----------------|------------|
|                      | n          | %          | n                   | %          | n               | %          |
| Anatomy              | 0          | 15         | 6.7                 | 225        | 93.3            |
| Biochemistry         | 22         | 9.1        | 45.2                | 110        | 45.7            |
| Pathology            | 0          | 21         | 8.7                 | 220        | 91.3            |
| Pharmacology         | 1          | 0.4        | 7.5                 | 222        | 92.1            |
| Physiology           | 8          | 3.4        | 91                   | 142        | 58.9            |
| Social sciences      | 12         | 5          | 71                   | 29.5       | 158             | 65.5       |

Values are no. (n) and percentage of responses. The clinical relevance ratings of the Basic Science Retention Examination (BSRE) disciplines is shown. Overall, the students and clinicians rated anatomy, pathology, and pharmacology as more clinically relevant than biochemistry, physiology, and social sciences. There were 93.3% of the students who considered anatomy clinically relevant, whereas 92.1 and 91.3% considered pharmacology and pathology, respectively, to be clinically relevant. In contrast, 65.5, 58.9, and 45.7% considered social sciences, physiology, and biochemistry, respectively, to be clinically relevant. There were no significant differences in clinical relevance ratings between the students and the clinicians for each discipline: anatomy, $X^2 = 10.1, P = 0.06$; biochemistry, $X^2 = 13.9, P = 0.06$; pathology, $X^2 = 2.6, P = 0.92$; pharmacology, $X^2 = 10.0, P = 0.19$; physiology, $X^2 = 8.3, P = 0.30$; and social sciences, $X^2 = 6.0, P = 0.53$.

quality of the BSRE. Thematic analysis identified three major themes: relevance, impact on learning, and continuity.

Relevance. The students and clinicians noted that the examination was a positive experience, useful and highly relevant to the course. They all felt that the test items were moderately difficult, with anatomy and biochemistry being the most difficult domains. They also indicated that the exam had a good coverage of the breadth of knowledge, and the questions were mostly clinically relevant.

This was a useful experience and confirming of my retention and application to knowledge. Thank you for the opportunity and the feedback. [Bachelor of Medicine, Bachelor of Surgery year 2 (MBBS 2)]

It was a highly relevant, clinical based exam focusing on core basic science knowledge. (MBBS 4)

Basic science is probably the most important part of a Dr’s foundation of knowledge. It needs to be stressed upon right in the beginning of Med School. (Clinician)

Impact on learning. The student participants indicated that the examination provided them with an opportunity to identify their strengths and weaknesses in the various subjects while consolidating knowledge. They also stated that the performance/feedback data were true reflections of their strengths and/or weaknesses in the basic sciences. The clinicians confirmed that the basic sciences provide foundational knowledge.

I performed best on the domain I had a prior degree in and worst in the area that I placed the least amount of emphasis in ... anatomy. (MBBS 6)

Very useful in finding out what our natural strengths and weakness are without any bias change by SWOTVAC study. (MBBS 4)

I think it’s important to have a good grasp of the basic science as a foundation, because it helps later with understanding. (Clinician)

Continuity. The participants suggested that the basic science examination should be made a continuous and mandatory exercise, to emphasize its importance and foster lifelong learning. The students felt this approach would make them study/ revise the basic sciences more regularly. These views and opinions informed the main study.

Should be done early and mandatory—we need to be reviewing basic science content and this is a good means to ensuring we are doing that sufficiently. (MBBS 4)

Wish there was more of this—indicates what your weaknesses are and emphasizes lifelong learning. Particularly now preclinical exams are effectively semester by semester knowledge. (MBBS 3)

I think this was good and would like to see it done again. Really shows things that are important to be revised [sic]. (MBBS 5)

I would do terribly! You forget all of this over time. (Clinician)

Main Study

A total of 563 medical students and 120 residents (100% response rate) participated in the 2016 examination. The mean ages were 22.6 yr (SD 3.7) and 34.2 yr (SD 6.7) for the students and residents, respectively. Domestic students comprised 88% of the participants, and 58% were female. The mean test score was 52% (SD 6.0; range = 15–87%). The KR-20 reliability was 0.72, and the standard error of measurement was 3.39.

As shown in Fig. 1, the overall mean performance in 2014 was significantly higher than in 2016 [59% (SD 12) vs. 52% (SD 10), $t (166) = 6.03, P < 0.001$]. On the average, performance scores in 2014 were 7% higher than the performance scores in 2016. In general, performance of the 2014 cohort was significantly better in biochemistry [52% (SD 14) vs. 36% (SD 15), $t (195.6) = 11.44, P < 0.001$] and pathology [77% (SD 18) vs. 58% (SD 20), $t (685) = 9.44, P < 0.001$]. Similarly, the 2014 cohort had significantly higher scores in pharmacology [56% (SD 21) vs. 44% (SD 18), $t (685) = 6.10, P < 0.001$] and physiology [66% (SD 17) vs. 58% (SD 15), $t (685) = 4.91, P < 0.001$]. However, the 2016 cohort obtained higher average scores in social sciences [69% (SD 16) vs. 57% (SD 18), $t (685) = -7.69, P < 0.001$]. Furthermore, there was no difference in the performances of the two cohorts in anatomy [45% (SD 19) vs. 44% (SD 17), $t (685) = 0.35, P = 0.73$]. Male students had significantly higher ($P < 0.001$) scores than the female students, except in social sciences, where female students performed better than male students. Domestic students had significantly higher ($P < 0.001$) scores than international students in overall and most individual discipline scores. Figure 2 shows the percent mean scores across disciplines for all four participant groups (year 2, 4, and 6 students and residents). Overall performance showed progressive increases from year 2 to 6 [44% (SD 11) vs. 58% (SD 13) vs. 67% (SD 12), $F(3,682) = 129.39; P < 0.001$], except in physiology when year 2 students outperformed all other participant groups [60% (SD 24) vs. 52% (SD 25) vs. 55% (SD 24) vs. 55% (SD 25), $F(3,682) = 4.70, P = 0.003$]. There were no significant differences between year 6 students and residents in anatomy and overall mean scores (Fig. 2). Similar discipline-specific performance trends were observed, irrespective of year of study. The highest scores were obtained in pathology and social sciences, whereas the lowest scores were in anatomy, biochemistry, and physiology.
There were moderate correlations between students’ basic science test scores and their summative examination scores within the medical program. The correlation coefficients in 2014 and 2016 were 0.63 and 0.54, respectively ($P < 0.001$). The quartile ranks for performances in the summative MCQ test was the same for 42% of students. Furthermore, the highest scoring students on the basic science test in 2014 also performed well in the 2016 BSRE, whereas the lowest scoring students in the 2014 exams had failed and repeated the academic year. There was also a moderate correlation ($r = 0.50$) between residents’ scores on the basic science exam and their internal formative clinical exam.

**DISCUSSION**

This study highlights the value of assessment-related interventions on student learning. The pilot test showed variations in perceptions of relevance of the basic sciences and assessment scores, but also showed that knowledge (as measured) of basic sciences improved from years 1–4 and then was maintained to the early postgraduate period. The value of the test was recognized as an additional guide to learning and reinforcer of integrating basic science and clinical knowledge. The results of the main study then largely confirmed these findings and demonstrated correlations with other formative and summative assessments.

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![Fig. 1. Comparison of 2014 and 2016 students’ performance in the various Basic Science Retention Examination (BSRE) disciplines. Overall mean performance score in the BSRE was significantly higher among the 2014 cohort ($n = 124$; 59% (SD 12)) in comparison to the 2016 cohort of students ($n = 563$; 52% (SD 10); $t (166) = 6.03, P < 0.001$). In general, performance of the 2014 cohort was significantly better in biochemistry [52% (SD 14) vs. 36% (SD 15), $t (195.6) = 11.44, P < 0.001$], pathology [77% (SD 18) vs. 58% (SD 20), $t (685) = 9.44, P < 0.001$], pharmacology [56% (SD 21) vs. 44% (SD 18), $t (685) = 6.10, P < 0.001$], and physiology [66% (SD 17) vs. 58% (SD 15), $t (685) = 4.91, P < 0.001$]. However, the 2016 cohort obtained higher average scores in social sciences [69% (SD 16) vs. 57% (SD 18), $t (685) = -7.69, P < 0.001$]. There was no difference in the performances of the two cohorts in anatomy [45% (SD 19) vs. 44% (SD 17), $t (685) = 0.35, P = 0.73$]. To ensure that participants in both cohorts were similar, only the second-year, fourth-year, and sixth-year students of the 2014 cohort were included in comparison to the 2016 cohort.

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![Fig. 2. Comparison of medical students and residents’ performances in the various Basic Science Retention Examination (BSRE) disciplines in 2016 ($n = 563$). This figure shows the percent mean scores across disciplines for all four participant groups (year 2, 4, and 6 students and residents). Overall performance scores progressively increased from year 2 to 6 [44% (SD 11) vs. 58% (SD 13) vs. 67% (SD 12), $F(3,682) = 129.39; P < 0.001$], except in physiology, where year 2 students outperformed all other participant groups [60% (SD 24) vs. 52% (SD 25) vs. 55% (SD 24) vs. 55% (SD 25), $F(3,682) = 4.70, P = 0.003$]. There were no significant differences between year 6 students and residents in anatomy [45% (SD 25) vs. 47% (SD 25), $F(3,682) = 6.80, P = 1.00$] and overall mean scores [67% (SD 12) vs. 64% (SD 11), $F(3,682) = 129.39, P = 0.129$]. However, there was a significant difference between the residents’ performance in comparison to year 2 and 4 students [64% (SD 11) vs. 44% (SD 11), $F(3,682) = 129.39, P < 0.001$ and 64% (SD 11) vs. 59% (SD 13), $F(3,682) = 129.39, P = 0.001$]. Similar discipline-specific performance trends were observed, irrespective of year of study. The highest scores were obtained in pathology and social sciences, whereas the lowest scores were in anatomy, biochemistry, and physiology.](http://advan.physiology.org)
The goal of formative assessment is to stimulate learning in a desirable direction and foster deep learning approaches (43). In 2014, the pilot study was voluntary, and students who were motivated to participate in the study undertook the examination. However, in 2016, BSRE was included in the curriculum as an on-going formative assessment for medical students in years 2, 4, and 6 to aid self-directed learning and application of basic science knowledge throughout the curriculum. There was a slight decline in the KR-20 reliability index in the 2016 main study. The drop in the reliability score may have been due to the wider spread of scores in this examination, as the whole year cohort was included in the study. Conversely, the pilot study was voluntary, and students who participated in it may have been high-achieving and motivated students; hence the narrower spread of scores and higher reliability index in the 2014 pilot study.

Although, the students performed better in the pilot study than in the main study, students’ performances in both tests, however, were lower than expected. The higher performance in the pilot study compared with the main study may be because the students who participated in the pilot study were presumably more motivated and engaged. However, students’ mean performance in the summative examination were higher than their mean performance in the study tests (pilot and main). The observed lower performances in the study tests compared with the summative assessment may be because the tests were formative assessments, and students were not required to pre-study specifically for these tests. Previous studies have shown that students’ academic performances are influenced by their study strategies (19, 45). However, examination performance in a formative assessment is an indicator of success or failure in a summative assessment (21), as evidenced in this study, where students who passed the BRSE also performed well in the summative examination. Additionally, the lower performance could be an indication that core revision and assessment of the basic sciences in the clinical years is not as explicit as it should be and could be developed further. While the JCU curriculum emphasizes early clinical experiences for students, the basic sciences are sparsely revisited in the clinical years. Hence, findings from this study could be used to inform and improve teaching and assessment processes in the clinical years of the course.

Comparative analysis of performance revealed that the higher performances were recorded in pathology, physiology and social sciences in the 2014 and 2016 cohort, whereas the least performances were observed in anatomy and biochemistry. This confirms our laboratory’s previous findings in another setting (24). In addition, there were also some differences in scores for some individual disciplines, some higher and some lower. There may be several explanations for the low performance and the differences, including choice and quantity of the test questions, curriculum content, teaching methods, assessment blue-printing, or perceived importance and relevance by students. The choice of test questions may have influenced test results, given that only 10 questions were used per discipline. The number of questions used may not have provided a valid sample for reliable analyses of individual disciplines. However, MCQ is considered as a valid and reliable assessment tool that assesses knowledge comprehension and application (2). In addition, given that the study was conducted in two different years with different participant groups and yet a similar trend was observed, this may be an indication that the questions may be sufficient to assess the individual disciplines. Furthermore, there may have been rote memorization at the expense of understanding, lack of application in clinical years (8), or lack of reinforcement when learning clinical knowledge. Moreover, increasing time interval between initial learning and accessing retained memory can impede problem-solving, especially when contexts are different (29). Perceived importance and relevance also play a role, with students often associating importance with “severity” of assessment (3). In our study, the low performance in anatomy and biochemistry in the two phases of the study may be partially related to the perceived clinical relevance of the disciplines. In a previous study, biochemistry was considered the least clinically relevant subject and was associated with poor performances in the examination (12). In other cases, tradition plays a major role. For example, students often rate anatomy as the most important basic science subject (18), and yet medical programs vary considerably in their anatomy content. The social sciences are often not so popular with medical students, but the higher ratings in the pilot study for their relevance by clinicians may be an indication of better appreciation of the subject with years of experience.

Clinical exposure has been shown to correlate with perception of the clinical relevance of basic science subjects (12). In the pilot study, the similarity of ratings by students, interns, and clinicians may reflect their substantial early clinical exposure in a highly integrated program (38). Furthermore, the observed higher positive correlations between items answered correctly and clinical relevance ratings for the senior students could be a reflection of their full understanding of the relevance of the basic sciences.

In both phases of the BSRE (pilot study and main study), the overall performance and performance in each discipline increased progressively with increasing year of study, except for physiology. The better performance observed among the second-year students in physiology compared with other year groups may be due, in part, to the fact that the knowledge gained in this subject in the preclinical years is not explicitly reinforced in the senior/clinical years at JCU, in comparison to other basic science subjects. Furthermore, the lower performance in physiology among the senior medical students may be associated with the inability to recall the physiological mechanisms, despite having good clinical knowledge of a condition (22). Evidence suggests that clinical knowledge may be memorized and learned without understanding its basic background (22). This finding is consistent with previous research, where knowledge loss of physiology was reported among senior undergraduate students (8, 22). This may provide an opportunity to revisit physiology teaching in the clinical years of the JCU MBBS course. Reinforcing the physiological mechanisms of diseases in the senior years may have value and help students to have a solid foundation in the physiological underpinnings of health and disease (46). However, the absence of any significant difference in basic science knowledge retention between GP residents and year 6 medical students suggests that basic science knowledge was not rapidly lost in this study population. This is in contrast to previous studies, which have documented a decline in basic science retention among students with increasing years of study (8, 12, 22, 23). The observed improved performance with increasing years of
study echoes the results of our laboratory’s previous study (24). Furthermore, perceived relevance may vary according to the topic and the experience or ability of the student.

The results indicate that the introduction of a formative basic science assessment may in itself be an intervention that sends a strong signal to students that this subject matter is important. Evidence from the literature suggests that evidence-based changes in teaching and assessment in medical education can facilitate active learner participation, promote lifelong learning, and help students make decisions about how and when to modify their learning (40). The constructivism theory of adult education states that learners base their knowledge on what they already know, experience, and perceive (25). Many studies have shown that assessment is an important element of education that drives learning. When coupled with effective feedback, it encourages students to perform better. In addition, assessment results can also aid faculty in ascertaining whether the learning objectives of the curriculum have been attained (42, 43). Teaching and assessing basic sciences in a manner that integrates with clinical knowledge may foster longer-term retention, transfer, and application in clinical practice (12).

Our results also illustrate the developmental role and value of the basic sciences, with the moderate correlation of performance data in the basic science and summative exams. Should a programmatic assessment approach be adopted (39), the BSRE would be a useful contribution. This would increase the rewards for strong student performance. As with progress testing (41), frequent testing of medical students’ knowledge of basic sciences throughout a primary medical program, combined with effective feedback on their performance, will help students to achieve mastery of learning outcomes that include application of basic sciences in clinical practice (4).

The complex question of early intervention and remediation is highlighted by the finding that students with the lowest scores in the 2014 pilot had all failed the year and had to repeat. This may indicate the efficacy of the BSRE as a remediation tool to highlight students with weaker basic science knowledge. It could also serve as a prompt to students to retain awareness of the basic sciences.

Limitations of the Study

This study was conducted in a single institution, with medical students in only one primary medical program, although the GP residents were graduates of several medical schools. The choice of test questions could have influenced test results, and 10 questions per discipline may not provide a valid sample for reliable analyses of individual disciplines. The scores of early trainees in specialties other than GP may have been different. Further similar studies in more locations are required to address these concerns.

Conclusion

The basic sciences are a substantial component of primary medical education and play an important developmental role in facilitating efficient learning for clinical practice. Successful incorporation of the basic sciences into clinical practice through understanding, retention, and transfer of acquired knowledge may depend on strategies that make explicit their relevance to clinical practice. Integration in curriculum should be matched by integration in assessment, such as linking the application of basic science knowledge to clinical scenarios (10, 46). Additionally, clinically oriented scenario-based assessment may strengthen students’ perceived importance and relevance of the basic sciences to clinical practice and may foster increased investment in learning and retention of basic science curriculum content (13). Increased formative assessment increases feedback to learners and may help identify weaknesses in teaching. In addition, results are likely to correlate with those of other assessments and may be a worthwhile contribution to a programmatic assessment approach.

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DISCLOSURES

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

AUTHOR CONTRIBUTIONS

B.S.M.-A. conceived and designed research; B.S.M.-A., P.H., and P.-A.T. performed experiments; B.S.M.-A. and F.A. analyzed data; B.S.M.-A., F.A., P.H., P.-A.T., T.S.G., and R.H. interpreted results of experiments; B.S.M.-A. prepared figures; B.S.M.-A. and F.A. drafted manuscript; B.S.M.-A., F.A., T.S.G., and R.H. edited and revised manuscript; B.S.M.-A., F.A., P.H., P.-A.T., T.S.G., and R.H. approved final version of manuscript.

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