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A summer prematriculation program to help students succeed in medical school

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Abstract Medical schools with a diverse student body face the challenge of ensuring that all students succeed academically. Many medical schools have implemented prematriculation programs to prepare students from diverse backgrounds; however, evidence on their impact is largely lacking. In this study, we analyzed participants' demographics as well as the impact of the prematriculation program on Year 1 performance. Predictive validity of the program was assessed and compared to other traditional predictors, including grade point average (GPA) and Medical College Admission Test (MCAT) scores and subscores. Linear mixed effect models determined the impact of the prematriculation program, and linear regression analysis assessed the predictive value of the overall score in the prematriculation program and other traditional predictors. Demographics of students participating in the prematriculation program from 2013 to 2015 ($n = 75$) revealed a significantly higher prevalence of academically disadvantaged students including older students, students with lower GPA and MCAT scores and students of racial and ethnic populations that are underrepresented in medicine, compared to non-participants ($n = 293$). Participants performed significantly better in Year 1 courses that were covered in the prematriculation program compared to courses that were not covered. The overall performance in the prematriculation program correlated significantly with Year 1 performance and was found to be a strong predictor for Year 1 performance. This study suggests that a prematriculation program can help students to succeed in the first year of medical school. The results have implications for medical schools seeking to implement or evaluate the effectiveness of their prematriculation program.

Keywords Prematriculation program · Academic performance · Prematriculation variables

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Introduction

Health professions educators share the common goal of creating a learning environment that allows students with vastly different prerequisite knowledge to successfully progress through the curriculum on schedule. This goal is particularly challenging in medical education, as students navigate through a curriculum that delivers large amounts of content in a relatively short amount of time. A number of factors can increase the risk of academic difficulty for some students, such as longer intervals between graduation from college or graduate school and the start of medical school and lower grade point average (GPA) and/or standardized test scores (Andriole and Jeffe 2010; Dunleavy et al. 2013; Huff and Fang 1999; Kleshinski et al. 2009). Students who enter medical school with one or more of these risk factors are more likely to withdraw or be dismissed from medical school, or to graduate after having failed the United States Medical Licensing Exam (USMLE) Step 1 and/or Step 2 Clinical Skills (CK) at least once (Andriole and Jeffe 2010). Experiencing academic difficulty also has a negative impact on the overall quality of life and is associated with an increased incidence of depression (Stewart et al. 1995). Therefore, medical schools ideally should take a proactive approach minimizing the academic difficulties encountered by academically disadvantaged students.

Medical schools use various approaches to help students who are academically at risk successfully master their curricula and become physicians. Some of these schools provide a more flexible curriculum that allows students to increase the time available for studying the material. Some curricula incorporate optional study time into each block, while others provide 1- and 2-year options to complete certain portions of the curriculum (Jelsing et al. 2007; Peacock and Grande 2015; Wackett et al. 2016).

Another strategy is to offer a prematriculation program to help prepare students to master the curricular material in the standard time. These programs can be offered to all students who have been admitted (Battistella et al. 2001; Richardson and Saffran 1985; Stoddard et al. 2008; Wilson et al. 2011) or can target students academically "at risk". Most medical schools define "at risk" students based on their ethnic and socioeconomic characteristics (Carroll and Lee-Tyson 1994; Hairrell et al. 2016; Hesser and Lewis 1992a, b; Thompson and Weiser 1999; Williams 1999). Some schools also include academic variables such as GPA and MCAT scores in their criteria (Seifert and Harper 2007). Specifically, the goals of these programs include better academic preparation (Wilson et al. 2011), optimization of study strategies (Miller 2014; Richardson and Saffran 1985), improved social support (Awad et al. 2014), and increased familiarity with the campus and the community (Hesser and Lewis 1992a). There are also some benefits reported from such programs in non-health professions. Participation resulted in improved academic skills (Strayhorn 2011), increased engagement in social activities, enhanced familiarity with university services and the ability to use academic and social support services (Cabrera et al. 2013; Sablan 2014; Strayhorn 2011).

A significant proliferation of medical prematriculation programs has been reported in the U.S. in recent years (Heck et al. 2017). Although a few prematriculation programs can be found in other countries (Awad et al. 2014; Carmichael and Taylor 2005), most studies to date focus on prematriculation programs in the U.S. These programs are an average of 4 weeks long and predominantly cover basic science material with lectures as the primary instructional method (Heck et al. 2017). The average number of exams is one, and most programs do not require remediation or have meaningful consequences for students who perform poorly in the program (Heck et al. 2017). There is significant variability between programs in terms of structure, content and intensity, which can influence the benefits gained by the participating students.

The real impact of existing prematriculation programs on medical school academic performance is largely undocumented. Many investigators who have documented improvement in skills or perceived knowledge did so by comparing students' scores on pretests at the start of the program to scores at the conclusion of the program, but did not assess the impact on subsequent medical school academic performance (Awad et al. 2014; Battistella et al. 2001; Miller 2014; Musick and Ray 2016).

Of the few studies assessing the impact of prematriculation programs on Year 1 medical school performance (Hairrell et al. 2016; Hesser and Lewis 1992a; Seifert and Harper 2007; Thompson and Weiser 1999), only one reported meaningful improvement (Wilson et al. 2011). This program made two short online modules available to all students prior to the start of medical school. Completion of the biochemistry module translated into a significantly higher performance in the Year 1 biochemistry course, but completion of the physiology module had no effect on performance in physiology. In addition to the limited amount of subjects covered in their program, there is a lack of accountability for student learning, as students were not tested in this program.

A major limitation of this study as well as the remainder of the existing research examining the direct impact of prematriculation programs on student performance in subsequent years is that test scores of participants are compared to test scores of non-participants, even though participants are unlikely to be representative of the class as a whole.

The University of California, San Diego, School of Medicine (UCSD SOM) offers a rigorous, 7-week prematriculation program, Core Topics in Biomedical Sciences (CTBS), to all students who have been accepted. Academically disadvantaged students, as described earlier, are highly encouraged to attend by the Associate Dean for Admissions and Student Affairs. CTBS covers topics in Year 1 basic science courses that require the mastery of large amounts of information that students find particularly difficult and have higher failure rates. One goal of CTBS is to improve academic performance in Year 1 by enhancing students' expertise in selected subjects prior to the start of medical school and modeling the pace and intensity of the curriculum. For students who encounter academic difficulty during medical school, there are other mechanisms within the curriculum that provide flexibility such as remediation exams during the breaks. For some of these students, they may decide (in concert with advisors and deans) to extend their time in the pre-clerkship curriculum by typically 1 year.

In this study, we analyzed demographics and other characteristics of CTBS participants. We calculated the difference between students' academic performance in Year 1 courses that included topics covered in CTBS and Year 1 courses that did not include CTBS topics. Regression analysis was used to determine if CTBS scores predict Year 1 performance.

Methods

Students' demographics

Demographic data from students matriculating at UCSD SOM from 2013 to 2015 were obtained from administrative records. Gender, major, age, race/ethnicity, GPA, Biology, Chemistry, Physics and Math (BCPM) GPA, Medical College Admission Test (MCAT) Total Score, MCAT Biological Sciences, MCAT Physical Sciences and MCAT Verbal

Reasoning Score were compared between medical students who completed the CTBS course and those who did not.

Undergraduate major was categorized into Natural Science, Social Science, or Other. The Other category included majors in Arts and Humanities as well as Business. Race or ethnicity was categorized as White, Asian, underrepresented in medicine (URiM) or Other. URiM students included African American, Hispanic or Latino and American Indian or Alaska Native. The Other category included students that indicated mixed races.

Design of the CTBS program

CTBS is a 7-week program with 118 scheduled instructional hours and consists primarily of live lectures (85% of instructional hours) with some problem-solving sessions (6% of instructional hours) and anatomy/histology laboratory sessions (8% of instructional hours). Four major subject areas are taught in 118 h including cardiovascular physiology (50 h), pulmonary physiology (18 h), immunology (26 h), and molecular biology/genetics (24 h). These four subject areas are defined as "supported" because they are directly related to specific Year 1 courses. Other Year 1 courses covering the subjects of neurology, endocrinology, hematology, microbiology, gastrointestinal physiology, kidney physiology, and the musculoskeletal system, are defined as "non-supported" courses and are not included in CTBS.

Students were administered a total of six exams during the 7-week CTBS program that consisted of one best answer multiple-choice questions similar to the question style encountered in Year 1 of the curriculum. Three exams covered cardiovascular and pulmonary physiology, two exams covered immunology, and one exam covered molecular biology/genetics. The last exam in each topic area, and the only exam in molecular biology/genetics was cumulative. There were exam review sessions following each exam to provide students with detailed explanations and feedback. Students who did not pass an exam were required to take and pass a make-up exam as part of the remediation component of the program. Students who are unable to satisfy the remediation requirement do not pass or withdraw from the program. While this would be reported on their undergraduate transcript, it does not affect their medical school matriculation status.

Performance in Year 1 medical school courses and cumulative exam scores

The impact of the prematriculation program on students' performance was determined using z-scores for each student from each exam during Year 1 of medical school. Z-scores were used as an outcome measure to minimize the effect of variations in exam difficulty. Z-scores were calculated using records of students' exam performance and mean performance of the entire class. For courses with more than one exam (e.g., midterm and final examination), the average z-score was used. For each of the eleven courses during Year 1, an average z-score for all 75 CTBS participants (2013–2015) was calculated. The percent difference on every exam was calculated by subtracting the percent performance of each CTBS student on each of the course exams from the class mean.

To determine which variable best predicted performance in Year 1 medical school, an average exam score from all eleven courses during Year 1 was calculated. The average CTBS score was calculated from a total of six separate CTBS exams.

Statistical analysis

Statistical analysis was conducted using GraphPad PRISM (version 5.0b) and R statistical software (R Core Team 2014), the R package lme4 (Bates et al. 2015) and lmerTest (Kuznetsova et al. 2015). Chi-squared tests were used to compare gender, race/ethnicity and major of CTBS matriculates and non-matriculants. Age at admission, GPA, BCPM GPA, MCAT Total Score, MCAT Biological Sciences, MCAT Physical Sciences and MCAT Verbal Reasoning Score were compared using an unpaired *t* test. Z-scores and the percent difference of CTBS students from the class mean in all courses were compared using a paired *t* test. The Bonferroni method was used for multiple comparison correction.

A linear mixed-effects model was used to determine the effect of the prematriculation program on students' z-scores. The variables, supported versus non-supported courses, were entered as fixed effects. The model used applicant IDs as a random effect to account for the repeated measures.

Linear regression analysis was performed to determine students' characteristics associated with academic performance in Year 1.

Ethical approval

The UC San Diego Human Research Protection Program granted Institutional Review Board approval.

Results

Demographics and student participation

All students who matriculated from 2013 to 2015 were analyzed regarding their demographics and other academic characteristics (n = 368); 20% of the students participated in CTBS (n = 75/368). CTBS participants (n = 75) were compared to students who did not choose to participate in the CTBS program (n = 293) (Table 1). There were significant differences in race/ethnicity, age, GPA (total GPA and BCPM GPA) and MCAT scores (Total MCAT, Biological Sciences, Physical Sciences and Verbal Reasoning scores). CTBS students were on average 1.1 years older than non-participants at admission. Twenty-eight percent (n = 21/75) of the CTBS students were White compared to 44% (n = 129/293) of the non-CTBS students. URiM students accounted for one-third of the CTBS students (n = 23/75, 31%) compared to 15% (n = 43/293) of non-participants. The total GPA of CTBS students was on average 0.2 lower and their BCPM GPA score 0.1 lower. CTBS students' MCAT scores also were significantly lower than those of non-participants. No significant differences were found regarding gender and undergraduate major.

Effect of participation in CTBS on performance

To investigate whether CTBS improved performance on Year 1 medical school exams, students' z-scores for all sixteen exams taken in eleven courses in Year 1 were determined. Figure 1a shows the average z-scores of the 75 CTBS participants in the four "supported" courses (Cardiovascular System, Pulmonary System, Immunology, and Molecular

Table 1 Demographic characteristics of students participating in CTBS compared to non-participants

Characteristic	CTBS	Non-CTBS	p value[a]
Gender, n (%)			0.33[b]
Male	43 (57)	147 (50)	
Female	32 (43)	146 (50)	
Race/ethnicity, n (%)			**<0.01**[b]
Asian	30 (40)	115 (39)	
White	21 (28)	129 (44)	
URiM	23 (31)	43 (15)	
Other	1 (1)	6 (2)	
Age at admission			**<0.01**[c]
Mean (SD)	24.9 (3.5)	23.8 (2.9)	
GPA, mean (SD)			
Total GPA[d]	3.6 (2.5)	3.8 (1.8)	**<0.0001**[c]
BCPM	3.6 (2.9)	3.7 (2.1)	**<0.0001**[c]
MCAT, mean (SD)			
Total MCAT	31.9 (3.3)	34.5 (3.1)	**<0.0001**[c]
Biological Sciences	11 (1.5)	12 (1.5)	**<0.0001**[c]
Physical Sciences	10.5 (1.6)	11.7 (1.6)	**<0.0001**[c]
Verbal Reasoning	10.3 (1.4)	10.8 (1.4)	**0.02**[c]
Major, n (%)			0.2[b]
Natural Science	59 (78)	253 (86)	
Social Science	12 (16)	27 (9)	
Other	4 (5)	13 (4)	

[a] Significance ($p < 0.05$) is indicated in bold

[b] Chi square

[c] Unpaired t test

[d] GPAs are reported on a four point scale, with a grade of A = 4.0, B = 3.0, C = 2.0, D = 1.0

Biology/Genetics) compared to the seven “non-supported” courses. The z-scores of the CTBS students in supported courses were generally higher than in non-supported courses. Pairwise comparisons yielded statistically significant differences between the z-scores of CTBS students in the Cardiology and Immunology course (supported course) compared to most non-supported courses (Gastrointestinal System, Renal System, Hematology, Neurology, Microbiology and the Musculoskeletal System courses; paired t test with Bonferroni correction, $p < 0.05$). Figure 1b depicts the actual percent difference of CTBS students on each exam compared to the class mean. Pairwise comparisons again yielded significant differences between the Cardiology and Immunology courses and above-mentioned non-supported courses (paired t test with Bonferroni correction, $p < 0.05$). To determine the overall impact of CTBS on exam performance, a linear mixed effects model was used. Z-scores were used as outcome and “supported” versus “non-supported” courses as fixed effects. A significant interaction between the z-score and the type of course (“supported” course versus “non-supported” course) with a beta-estimate of 0.3 ($p < 0.0001$) was determined (Table 2). The calculated beta-estimate represents the average z-score improvement in courses that were supported by the CTBS course. Power analysis revealed that with 75 subjects and a similar within and between subject variance, a beta as small as 0.15 can be detected with a power of 0.8 and a significance level of 0.05. The calculated beta was found to be 0.3, implying that the observed power is over 99%.

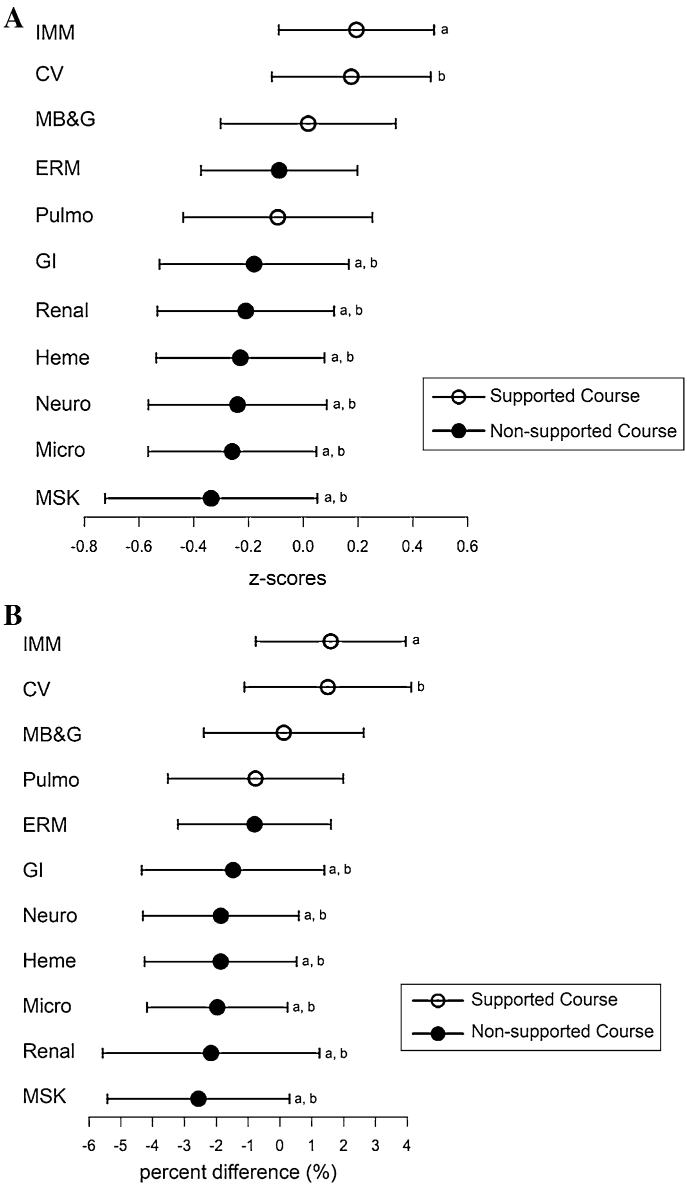

Fig. 1 CTBS students' performance in all eleven first year medical school courses. Z-scores **(a)** and percent difference from class mean **(b)** for each student (n = 75) in each exam were analyzed and depicted as mean ± 99% Confidence Interval. For each comparison, identical letters indicate the groups between which the statistical difference was significant (paired *t* test with Bonferroni correction, $p < 0.05$). *CV* Cardiovascular System course, *Pulmo* Pulmonary System course, *MB&G* Molecular Biology and Genetics course, *IMM* Immunology course, *Neuro* Neurology course, *ERM* Endocrinology, Reproduction and Metabolism course, *Heme* Hematology course, *Micro* Microbiology course, *GI* Gastrointestinal System course, *Renal* Renal System course, *MSK* Musculoskeletal System course

Table 2 Effect of CTBS covered material on performance in Year 1

Fixed effects	β-estimate	SE	DF	*p* value
(Intercept)	− 0.222	0.094	80.6	0.02
Supported course	0.3	0.05	747	**<0.0001**

SE Standard Error, *DF* Degrees of Freedom

Predictors of Year 1 performance

We next determined if the average CTBS exam score (an average of all six CTBS exams) could be used as a predictor of Year 1 performance. Linear regression analysis was conducted to determine the relationship between performance in Year 1 (an average exam score from all eleven courses during Year 1) and the following 10 potential predictors: age, gender, ethnicity, GPA, BCPM GPA, MCAT Total score, MCAT Biological Sciences score, MCAT Physical Sciences score, MCAT Verbal Reasoning score and CTBS score. The results of the linear regression analysis are presented in Table 3. Associations between each independent variable and Year 1 performance were analyzed. Ethnicity, GPA, BCPM GPA, MCAT Total, MCAT Biological Sciences, MCAT Physical Sciences and CTBS score all achieved a significant correlation with Year 1 performance. Being an URiM student was negatively correlated with Year 1 performance. Having a higher GPA, BCPM

Table 3 Univariable linear regression analysis for predictors of Year 1 medical school performance

Simple linear regression with predictor variables				
Variable	B	SE	*t* value	*p* value[b]
Age	− 0.393	0.214	− 1.833	0.071
Gender M	0.189	1.536	0.123	0.902
Ethnicity				
White	Reference			
Other	− 2.352	6.601	− 0.356	0.723
Asian	− 0.956	1.835	− 0.521	0.604
URiM	− 4.094	1.946	− 2.103	**0.039**
Major				
Natural Science	Reference			
Social Science	− 1.131	2.083	− 0.543	0.589
Other	− 3.113	3.400	0.916	0.363
GPA				
Total	0.0760	0.029	2.645	**<0.01**
BCPM GPA	0.056	0.026	2.193	**0.032**
MCAT				
Total	0.828	0.229	3.614	**<0.001**
Biological Science	1.946	0.502	3.878	**<0.001**
Physical Science	1.369	0.487	2.813	**<0.01**
Verbal Reasoning	0.593	0.584	1.015	0.314
CTBS score[a]	0.517	0.049	10.506	**<0.0001**

B Non-standardized regression coefficient, *SE* Standard Error, *DF* Degrees of Freedom

[a]F-statistic: 110.4 on 1 and 73 DF, $p < 0.0001$, Adjusted $R^2 = 0.60$ (for univariable model with CTBS score)

[b]significance is indicated in bold

GPA, MCAT Total, MCAT Biological Sciences, MCAT Physical Sciences or CTBS score translated into higher Year 1 scores.

Discussion

To our knowledge, this study is the first to provide compelling evidence that a prematriculation program can improve performance during Year 1 of medical school.

Furthermore, the average performance in our program was significantly associated with Year 1 performance and served as a strong predictor of Year 1 performance.

Many medical schools provide academic enrichment and support services for academically disadvantaged students in some measure. Prematriculation programs are one approach to increase success with a diverse student body. Most of these programs aim to improve performance in the first year of medical school. Exposure to relevant content before entering the Year 1 curriculum is intended to better match the experience of academically disadvantaged students with that of their classmates. Such courses can improve academic skills and enhance the adjustment of the students to their new environment. (Awad et al. 2014; Miller 2014) As with any program, metrics are needed to determine if the program is achieving its goals.

Our study utilized a novel approach to assess the effect of a prematriculation program on students' academic performance. Previous studies in health science and non-health science professions come with two major limitations. First, many of the studies determined perceived knowledge gain at the conclusion of the program. Second, all studies compared performance of students enrolled in a prematriculation course with that of non-participants. However, student cohorts differ in many ways, including preadmission scores, demographics and interpersonal variation in academic skills and experience. This reduces the validity of these studies. We bypassed this limitation by comparing each student's performance in courses that were supported by the prematriculation program to those that were not supported. Our methodology required that the content of the prematriculation program overlapped clearly and significantly with specific portions of the Year 1 curriculum. This allowed Year 1 exams to be categorized as testing content that had either been supported or not been supported by the prematriculation course.

Our results using this metric indicate that the curriculum in our prematriculation program is effective at improving student performance during Year 1. Although all Year 1 medical school courses are challenging, we chose topics for our prematriculation program that are particularly complex because of the many interactions between the concepts (van Merrienboer and Sweller 2010). The rapid pace of the curriculum often prevents students from learning underlying principles or patterns that can enhance understanding, retention and application. When faced with a topic that includes many elements interacting in multiple ways, students often spend their study time ineffectively trying to memorize individual elements. This prevents them from learning the underlying principles or patterns of interactions that would allow application and synthesis of the material. A prematriculation program teaching selected topics allows the students to develop a strong foundation for the underlying principles and then to better apply higher level problem solving when the material is encountered a second time. This layered approach allows students to recognize and consolidate the patterns into memory, rather than overwhelming the working memory with apparently unrelated elements.

In contrast to other prematriculation programs described in the literature, our prematriculation program provides the key components of test-enhanced learning: repeated tests, spaced over time, with post-exam feedback (Larsen et al. 2008). The frequent testing in CTBS encourages students to keep up with their studying in all subjects by providing testing soon after the learning experience. Integrative questions and cumulative exams require students to retrieve the material repeatedly. The exam reviews that follow each exam provide immediate feedback and an opportunity for students to correct their reasoning and enhance their retention. Remediation exams for students who fail the course exams provide additional opportunities for learning, retrieval and feedback.

High quality exam questions consistent with the style and difficulty of those in the Year 1 curriculum also contribute to the testing benefits of a prematriculation course. Students are provided with the opportunity to develop the most effective analytical approaches to complex scenarios, and frequent exams promote retention of these skills.

CTBS exam scores were found to be a significant predictor of Year 1 performance. This correlational data, the relationship to other variables, is an important piece of validity evidence (Downing 2003), supporting the meaningful interpretation of CTBS test scores. This suggests that having prematriculation performance data also provides an opportunity for intervention at the discretion of the school administration. Specifically, exam scores in prematriculation courses potentially can be used to identify the students at greatest risk from that cohort very early, and the administration can ensure that appropriate academic support is readily available.

The ultimate goal of all academic support services is to increase student success in medical school. In our study, we found that participation in CTBS resulted in an average increase of 0.3 standard deviations on a "supported" course exam. Using the specific standard deviation of student scores this translates into answering two or three additional questions correctly on a course exam. When considering the different pass lines for all of the "supported" courses, we identified a total of 11 instances when students scoring within 0.3 standard deviations above of the pass line. Therefore, CTBS may have prevented these students from failing at least one supported Year 1 course. Interestingly, four of these students had failures in two or more other courses. Since UCSD School of Medicine promotion policy allows a maximum of two make-up exams during the summer, the CTBS course may have even prevented some students from experiencing a delay in graduation due to the requirement to retake courses.

All prematriculation courses can be improved. The benefits of the CTBS course were not uniform across subjects as CTBS had the highest impact on exam performance in the Immunology and the Cardiovascular System course. We believe multiple variables contribute to this. First, cardiovascular physiology and immunology both have a lot of factual material that has to be integrated within a complex conceptual framework, making these two topics particularly challenging. In addition, these two courses had the highest ratio of CTBS instructional hours to actual Year 1 hours. Furthermore, the benefit of teaching pulmonary physiology in CTBS may have been attenuated by the fact that the Year 1 lectures closely follow a required textbook that contains lots of practice questions that were similar to the exam questions. Also, students may have had prior exposure to molecular biology and genetics topics, which would have lessened the benefit of this part of CTBS compared to cardiovascular physiology and immunology. Further analysis of these differences could lead to changes in hours spent per topic and the selection of topics in order to optimize the benefits of the program.

Limitations

This study has several limitations. First, this study presents the data of a prematriculation program at a single medical school and therefore the results may not be generalizable to other medical schools. Second, categorizing the Year 1 medical school courses as "supported" versus "not supported" was an oversimplification because CTBS did not support each course equally and completely. Our study did not account for these differences and only looked at the courses as if they were 100% supported, which may have underestimated the effect of the prematriculation course. Third, the type of student most likely to participate in the CTBS course might have influenced our results. Students who choose to participate in CTBS over the summer break might be self-selected as those with a higher motivation to successfully complete the first year of medical school. The results of this study might be different if the participants were randomly selected. Fourth, we did not analyze subgroups of CTBS students to identify a specific student group that most benefitted from CTBS. A larger student sample would be necessary to do this analysis. Fifth, in this study we only focused on the impact of the CTBS course on academic performance in Year 1 of medical school. Although we believe that this is an important outcome to measure, consideration of effects on Year 2 performance, long-term retention, student well-being, and emotional health should also be analyzed for a more complete understanding of the impact of the CTBS course.

Conclusion

As medical schools have made significant changes to diversify their matriculants by adopting a more holistic review of applicants (Bailey and Willies-Jacobo 2012; Deas et al. 2012; Girotti et al. 2015; Sokal-Gutierrez et al. 2015), an even greater effort is required to ensure that these students have a sufficient biomedical science background and academic preparation at the start of medical school. In this study, we provide a general framework on how a prematriculation program can be structured and, most importantly, evaluated to ensure program effectiveness and ongoing improvements.

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