The practice of medicine demands the highest possible skills in diagnosis and evidence-based therapeutics. However, cognitive errors can result in diagnostic and management errors. For example, misdiagnoses arise from flawed data gathering and/or misinterpretation of data. The best physicians think critically and problem solve through appropriate gathering and accurate interpretation of information.

Critical thinking (CT) is the skill of collecting appropriate information, accurately assessing information, and using that information to reach a considered conclusion. CT integrates six primary skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Previous research shows that health care professional trainees’ performance on critical thinking tests correlates with academic clinical decision-making as well as with academic success. Some research, though limited, suggests a positive relationship between CT skills and professionalism.

Despite the clear value of CT skills in health care professions, taking the approach of teaching CT skills to trainees is problematic. In some studies CT is unchanged by training programs, while in other studies CT improves with education. One way to ensure good CT skills in trainees is to select for trainees that already demonstrate those skills. To do this, programs could include CT skills assessment during medical school or residency selection. While many CT studies to date examined nursing, pharmacy, or dental hygiene, few studies have examined physicians in training. There is some work being done in the United Kingdom, where the situational judgement test incorporated...
into the UK Foundation Programme assesses constructs closely related to critical thinking. However, no published research has examined CT skills in family medicine residents.

The objectives of this study were to examine the relationship between CT skills of family medicine residents and other assessments. For this study, we chose to compare results on the California Critical Thinking Skills Test (CCTST) with the following performance measures: (1) performance on the College of Family Physicians of Canada board equivalent examination (CCPC) at end of training, (2) performance on academic examinations such as the Medical Colleges Admission Test (MCAT), and (3) file review and interview scores from the Canadian Residency Matching Service (CaRMS) selection process.

Methods
This research project was conducted in a large Canadian family medicine residency program from July 2011 to June 2013. The residency program is a 2-year program based on the Triple C curriculum, comprised of urban and rural family medicine block-time, integrated experiences, and off service rotations. Approval for this research was obtained from the institution’s Human Research Ethics Board.

Potential participants were urban and rural-based Canadian trained residents as well as international medical graduates residents entering the program on July 1, 2011 (n=74). All residents starting the residency program were required to write the CCTST (a validated tool to objectively assess CT skills) at the start, middle, and the end of their residency. At the time of writing the CCTST, support staff supervising test administration explained the study and provided the option of signing consent forms to participate in the research project.

Consent for the research study was obtained at two points: Consent 1 (obtained July 2011) requested access to the residents’ rotation evaluations, CCFP exam results, and the CCTST test scores. Consent 2 was obtained at the second writing of the CCTST in June 2012. This consent requested access to data on the Licentiate of the Medical Council of Canada exams (LMCC part 1 and Part 2), MCAT, and CaRMS file review and interview scores. For international medical graduates, consent was sought for other assessment components from their residency application process.

Data collection consisted of the following components:

California Critical Thinking Skills Test (CCTST)
The CCTST exam is a validated and reliable 34-item multiple-choice test. All three exam sessions were supervised with 45 minutes to complete. The exams were marked and scored. Results of the test were shared with each participant, but the research team was blinded to individual participant results.

Certification Examination in Family Medicine
The CCFP exam is a board-equivalent qualifying examination for Certification in Family Medicine. The CCFP exam results in three scores: a short answer written format, an oral component, and an overall result.

Resident File Review
Demographics of participating residents were collected at the beginning of the study. Resident files were searched for data by HLB. DR did random checks for accuracy of data collection. Resident files contained information on rotation evaluations, some demographic data, as well as data from residents’ application to the residency program (file review scores and interview scores).

Medical College Admission Test (MCAT)
The MCAT is a test of knowledge and reasoning that is required for admission to most medical schools. The MCAT has three sections: Verbal Reasoning, Physical Sciences, and Biological Science. MCAT scores were obtained by self-report and from medical student transcripts.

Analysis
Data were analyzed using R (v. 3.0.2; R Core Team, 2013) for descriptive, correlational, and predictive analyses. Relationships were explored using initially descriptive and correlational analyses. A regression model was calculated to determine which factors accounted for the greatest amount of variance in predicting CCFP exam scores.

Results
Of the 67 residents who gave consent to participate in the study, five were eliminated for having completed only one CCTST, and two were removed for being more than 3 standard deviations (SD) over the mean (P<.002), leaving 60 participants. Not all participants had values for all measures we consider, so we report the n for each measure we report.

Demographics
Residents were representative of previous and later cohorts, with a gender split of 45% male and a mean [SD] age of 27.9 [5.1] years. Fifty (83%) were Canadian medical graduates (CMG), while 10 were international medical graduates (IMGs). Residents came from a variety of educational backgrounds (Table 1), which is typical of this residency program.

CCTST
As participants wrote the CCTST at three points in time, a one-way within-subjects analysis of variance (ANOVA), using test-time as a factor, was conducted to determine if performance on the CCTST changed over time. The result (F(2,111)=1.62, P=.2) indicated that performance on the CCTST does not change significantly over time. We therefore used an averaged CCTST score for the remaining analyses.
To determine if demographics had a significant influence on CCTST performance, a two-way independent samples t test on the CCTST scores by gender was conducted (t (57.5)=1.25, P=.22), which indicated that there is not a statistically reliable difference in CCTST scores by gender (male average [SD]: 24.5 [3.0]; female average [SD]: 23.4 [4.0]). Age was a reliable negative predictor of CCTST score (r=-0.29; P=.02) but time since graduation from high school (r=-0.16; P=.20) showed no significant effect on CCTST score.

There was a reliable difference in average CCTST score between the 50 CMGs (average [SD]=24.54 [3.00]) and the 10 IMGs (average [SD]=20.80 [4.72]; t (10.51)=2.41, P=.04).

CCTST and Tests of Knowledge
Scores on the CCTST were compared with scores on both the MCAT and the CCFP examination. Pearson correlations were run to determine the strength of association between MCAT scores and CCTST scores for the 24 participants (all CMGs) for whom the MCAT scores were available. Significant positive correlations were found between CT skills and the MCAT. CCTST scores correlated positively with full scores (n=26, r=0.52; P=.003) as well as with each section score (verbal reasoning: r=0.56; P=.001; physical sciences: r=0.65; P=.0001; biological sciences: r=0.48; P=.005).

CCTST scores correlated reliably with both sections of the CCFP examination (n=57, 47 CMGs; orals: r=0.34; P=.01; short answer: r=0.41; P=.001).

CCTST and CaRMS Measures
To examine if CCTST predicted CCFP exam success better than current methods selecting residents into the residency program, we compared CCTST scores to the two main measures used for selection into our residency program: the CaRMS file score and the CaRMS interview score. The CaRMS file score includes all elements of a CaRMS application file evaluated by at least two faculty members. The CaRMS interview score involves individual interview scores from two people (a faculty member/clinical teacher and a current resident) that are averaged.

Score on the CCTST was compared to CaRMS application measures. There was no reliable correlation between the CCTST average score and either the CaRMS file score (n=51, r=-0.02, P>.9) or the CaRMS interview score (n=46, r=-0.10, P>.5).

CCTST as a Predictor of Success
There were 43 participants (34 CMG) for whom all information was available (CaRMS application measures, CCTST score, and CCFP orals and short answer scores). For these 43 participants, we undertook model analysis to find the best model for predicting CCFP oral and short answer scores. Models were compared using the Akaike Information Criterion (AIC), which allows for assessment of the relative goodness of fit of differently parameterized models in terms of the amount of information lost when each model is used to estimate the variable of interest.23

The models considered, and their relative success, are shown in Table 2. Only CCTST entered reliably into each model. Where a demographic predictor (age, gender, or CMG/IMG) entered in previously, it gets knocked out when CCTST is entered, and the CaRMS measures never enter after the CCTST: that is, there is no additional variance explained by the CaRMS measures after taking into account the variance explained by the CCTST. As indicated by the r² values, CCTST explained 11% of the variance on the CCFP oral exam (F [1,41]=4.87, P=.03), 23% on the CCFP written exam (F [1,41]=12.3, P=.001), and 20% of the variance in their average (F [1,41]=10.2, P=.003) (Figure 1).

Discussion
The results of this study support the belief that CT skills, as measured by CCTST, are associated with better performance and multiple measures of academic success in residency.7 The CCTST results were found to be a better predictor of academic success than the file review or interview scores from the CaRMS application process. CCTST scores were not influenced by age or gender and remained stable and constant over time, consistent with some previous research.10,11

The results of this study suggest that the CCTST may be useful as a tool for improving resident selection. Residency programs use a variety of selection criteria and tools when choosing medical students for residency training.24,25 Family medicine programs across Canada use CaRMS to assist with selecting students, where information such as MCAT scores, rotation evaluations, curriculum vitae, letters of support,

<table>
<thead>
<tr>
<th>Medical School</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Alberta</td>
<td>31</td>
</tr>
<tr>
<td>University of Calgary</td>
<td>3</td>
</tr>
<tr>
<td>University of British Columbia</td>
<td>7</td>
</tr>
<tr>
<td>Dalhousie University</td>
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<tr>
<td>University of Manitoba</td>
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<td>Northern Ontario School of Medicine</td>
<td>1</td>
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<td>University of Saskatchewan</td>
<td>1</td>
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<tr>
<td>McMaster University</td>
<td>1</td>
</tr>
<tr>
<td>International medical school</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 1: Medical Schools From Which Participants Graduated
proximately $10/test). These aspects and is relatively cost-effective (ap-

gram (which reduces perceived bias), is scored independently of the pro-

on paper or online in 45 minutes, 

CCTST can be administered either 

ing and pharmacy selection.

has been used extensively in nurs-

ical thinking assessment tool that 

The exception is the multiple mini-interviews or 

but the MMI has some 

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and participants were from one co-

Additionally, not all members of 

of the residency cohort participated in 

Future research should investigate the relationship 

between CT skills and academic outcomes 

within a larger group of participants, ideally across multiple 

programs. Further, future research 

is merited in the area of the rela-

ship between CT skills and non-

trainees. Other se-

tools may include a personal 

interview, simulated patient encoun-

ers, knowledge tests, and/or essays. 

There is conflicting evidence that 

any of these tools or criteria predict 

success in residency training, 

clinical performance, or on end-of-

training exams, but this research 

is complicated by the fact that suc-

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The CCTST is a validated critical thinking assessment tool that has been used extensively in nurs-

ing and pharmacy selection. The CCTST can be administered either on paper or online in 45 minutes, 

is scored independently of the pro-

gram (which reduces perceived bias), and is relatively cost-effective (approximately $10/test). These aspects 
suggest that the CCTST is a logis-
tically feasible way to assess for CT skills in the selection process.

Limitations and Directions for Future Research

While the results from this study are unique in family medicine and have potential implications for resident 
selection, it should be noted that the study included residents from only one family medicine program, and participants were from one co-
hort. Additionally, not all members of the residency cohort participated in the full study. Future research 
should investigate the relationship between CT skills and academic outcomes within a larger group of participants, ideally across multiple 
programs. Further, future research 
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Figure 1: Scatter Plot for Final Model Predicting Success on CCFP Exam Scores

- CCFP Oral Exam
- CCFP Written Exam

CCFP Written
\[ R^2 = 0.23 \]

CCFP Oral
\[ R^2 = 0.11 \]

Average CCTST Score

Standardized CCFP Score


