Training hospital providers in basic CPR skills in Botswana: Acquisition, retention and impact of novel training techniques☆

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Abstract

Objective—Globally, one third of deaths each year are from cardiovascular diseases, yet no strong evidence supports any specific method of CPR instruction in a resource-limited setting. We hypothesized that both existing and novel CPR training programs significantly impact skills of hospital-based healthcare providers (HCP) in Botswana.

Methods—HCP were prospectively randomized to 3 training groups: instructor led, limited instructor with manikin feedback, or self-directed learning. Data was collected prior to training, immediately after and at 3 and 6 months. Excellent CPR was prospectively defined as having at least 4 of 5 characteristics: depth, rate, release, no flow fraction, and no excessive ventilation. GEE was performed to account for within subject correlation.

Results—Of 214 HCP trained, 40% resuscitate ≥1/month, 28% had previous formal CPR training, and 65% required additional skills remediation to pass using AHA criteria. Excellent CPR skill acquisition was significant (infant: 32% vs. 71%, $p < 0.01$; adult 28% vs. 48%, $p < 0.01$). Infant CPR skill retention was significant at 3 (39% vs. 70%, $p < 0.01$) and 6 months (38% vs. 67%, $p < 0.01$), and adult CPR skills were retained to 3 months (34% vs. 51%, $p = 0.02$). On

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multivariable analysis, low cognitive score and need for skill remediation, but not instruction method, impacted CPR skill performance.

Conclusions—HCP in resource-limited settings resuscitate frequently, with little CPR training. Using existing training, HCP acquire and retain skills, yet often require remediation. Novel techniques with increased student: instructor ratio and feedback manikins were not different compared to traditional instruction.

Keywords

Developing countries; Emergency training; Resuscitation education; CPR; Chest compression; Competence; Resource-limited setting; Basic life support; Cardiopulmonary resuscitation; Manikin

1. Background

Globally, one third of deaths each year are due to cardiovascular disease, yet there is no strong evidence to support any specific method of CPR instruction in resource-limited settings. Ischemic heart disease accounts for more than 7 million deaths annually, with 80% of these in low and middle-income countries [1]. Cardiovascular diseases, including ischaemic heart disease, congestive heart failure, and stroke, account for more than a quarter of all deaths [2]. While successful resuscitation training has been shown to improve patient outcomes with newborn [3–7] and trauma resuscitation [8–11] in developing countries, there is no established, cost-effective training method for hospital-based providers in CPR. Additionally, study outcomes of CPR training in a low or middle income country have been limited to either knowledge acquisition [12–15], skills acquisition (using checklists) [16,17], or skills retention (using quantitative manikin output) [18]. To our knowledge, there are no studies that report quantitative measures of CPR skill acquisition and retention in a resource-limited environment.

In the absence of an established training program designed for resource-limited settings, there is often a disparity between patient needs, provider skills and resource availability. Local stake-holders, Non-Governmental Organizations (NGOs), and individual volunteers have implemented resuscitation training modified to available training resources instead of local healthcare needs [19]. In addition training outcomes are not evaluated or centrally tracked.

The dearth of literature describing CPR training in resource limited settings led to our study examining the educational impact of standard American Heart Association (AHA) Basic Life Support (BLS) cardiopulmonary resuscitation (CPR) training in Botswana, Africa, a resource limited setting. We hypothesized that hospital-based healthcare providers (HCP) [30] in a resource-limited setting would acquire significant knowledge and skills from standard CPR training and retain those skills at 3 and 6 months.

In any environment, it is a difficult task to determine whether to invest limited resources in instructor infrastructure with cheaper equipment or limited instructor core with more expensive technologically sophisticated training equipment. Unit-based Self-Directed Learning (SDL) has been developed to minimize instructor time and effort, and adjust the recertification process to adult learning principles [20,21]. Studies in *developed* countries have demonstrated that interactive training (video, feedback manikins, or SDL) may be as good as, if not superior to, traditional instructor-led courses [22–29]. Therefore, we additionally hypothesized that feedback training with manikins and limited instructor support would have similar effectiveness compared to standard CPR training with intensive instructor remediation.

2. Methods

2.1. Setting

Botswana's gross national income (GNI) per capita (PPP int. $) is 13,710 and 1341 (9.8%) of the GNI is spent on healthcare [31]. It is classified as an Upper Middle Income country by the World Bank [32]. Despite this, The World Health Organization classifies Botswana as a resource limited setting [30]. Botswana's Human Development Index is 0.633, which gives the country a rank of 118 out of 187 countries with comparable data [33]. The average life expectancy is 61 years, Under 5 Mortality Rate (U5MR) is 57/1000 live births, and prevalence of HIV is 248/1000 persons aged 15–49 [31]. The official language of Botswana is English. Setswana is spoken by approximately 78% of the population. Botswana's healthcare system includes 10 district hospitals and two referral hospitals, a national drug formulary consistent with the World Health Organization (WHO) Essential Drugs Programme and both private and government emergency transport services. At the district hospital level, general medical officers and nurses staff general medical wards, operating theatres, and the Accident and Emergency department. District hospitals have limited specialist availability and restricted capabilities for advanced airway, IV access, and defibrillation. The referral hospitals have intensive care units with capability for invasive mechanical ventilation, central venous access, invasive hemodynamic monitoring, peritoneal dialysis, and an expanded availability of specialists. In addition, University of Botswana Schools of Medicine and Nursing maintain academic affiliations and training programs at the referral hospital.

2.2. Participants and training

All in-hospital health care providers engaged in clinical care at Princess Marina Hospital (PMH, Tertiary/Referral) or Athlone (Secondary/District) at the time of the study with no previous CPR training in the past 12 months were eligible for training. Those providers unable to complete training or testing ($N = 1$) were excluded from the analysis. The American Heart Association approved all instruction methods prior to the study. For CPR skills assessment by AHA checklist criteria, a single rater was used for each station. Any HCP that did not achieve a passing score on either the written or skills test after initial training received additional remediation until they could demonstrate sufficient knowledge and skills to pass (i.e., 100% eventually were certified in BLS for HCP by 2009 AHA criteria before moving into the skill retention portion of the study). Each course was completed within 1 day, and training was conducted using the same small, highly trained group using scripted materials and schedule. The educational officer of each hospital gave AHA educational materials to each provider 1 week prior to their training date. All training and testing was conducted using the same type of manikins, standard Laerdal infant, child and adult models (Laerdal Resusci Anne, Laerdal Resusci Junior, Laerdal HeartCode BLS baby).

2.3. Study design

This investigation was a prospective, quasi-randomized interventional trial. The primary objective of this study was to determine the effectiveness of AHA CPR training to acquire and retain CPR skills for 6 months in a cohort of hospital-based HCP in a resource-limited setting. A secondary objective was to determine if novel teaching methods would have similar training effectiveness compared to instructor intensive standard training.

The primary outcome variable was Excellent *CPR*, prospectively defined as having at least 4 of the following 5 characteristics: chest compressions with adequate depth (≥23 mm for infant and ≥38 mm for adult), compression rate (≥90 and ≤120 CC/min), ≤20% of compressions with incomplete release (<5 mm), a no flow fraction (NFF) ≤0.40, and

ventilation rate (≥2 and ≤10 ventilations/min). This definition was adapted from our previously reported composite variable for 2-rescuer CPR, and NFF was increased from 0.3 to 0.4 because the simulated skill was single rescuer CPR [21]. Inter-rater reliability for the primary outcome variable, Excellent CPR, was not appropriate as Excellent CPR is a summary variable based on quantitative manikin output and was not reliant on subjective assessment by instructors.

All providers completed an initial demographic and work environment survey, a 20 multiple-choice question (MCQ) cognitive assessment (2005 AHA BLS exam A) in English, and single-rescuer simulated resuscitation scenario of both the infant and adult prior to training. Acquisition of knowledge and skills was assessed immediately following training, and retention was evaluated at 3 and 6 months. Providers repeated the MCQ and performed quantitative CPR skills on both the infant and adult manikin at each time point. During the CPR psychomotor skill evaluation sessions, providers performed single-rescuer CPR without manikin or instructor feedback [34].

Our study was a quasi-randomized to evaluate our secondary objective. The hospital training officer, blinded to instruction method, scheduled providers for CPR training. Courses were conducted in three ways:

Traditional instruction (TI) was the 2005 BLS HCP course (5 h of instruction, AHA 2005 BLS DVD use, student: instructor ratio of 6:1, student: manikin ratio of 2:1, and computerized feedback from the manikins turned off).

Limited Instruction with Feedback (LIwF) was the 2005 BLS for HCP course (5 h of instruction, use of AHA 2005 BLS DVD) with a student: instructor ratio of 18:1, student: manikin ratio of 2:1, with the automated computerized manikin feedback turned on (Laerdal Resusci Anne™ with skill reporter, Laerdal Resusci junior™ with skill reporter, Laerdal HeartCode™ BLS baby with HeartCode™ software via Laptop).

Self-Directed Learning (SDL) training consisted of HeartCode™ BLS for the training without an instructor and the automated computerized manikin feedback on. Student: manikin ratio was 1:2, but only a single manikin was used at a time. HeartCode™ BLS is an interactive, self-directed, comprehensive, computer-based training program from the American Heart Association.

2.4. Data analysis

Standard descriptive and univariate analysis was performed. Summary results are presented as the mean and standard deviation for normally distributed variables and median with interquartile ranges for variables that were not normally distributed. Continuous variables were analyzed using paired t-test for parametric and Wilcoxon signed-rank test for nonparametric variables. Differences between groups for discrete variables were tested with chi-square or Fisher's exact test. Significance was set at $p \leq 0.05$.

To evaluate for possible bias due to non-random loss to follow up and loss of interpretable data, we used paired testing where possible, and reported separate baseline scores for each set of comparisons.

In a multivariable model, differences in the retention rate over time and between groups were assessed using generalized estimating equations. Candidate variables were identified a priori, and included English fluency, working in an acute area (Intensive Care Unit, Accident + Emergency, Operating Room or “more than one ward” if at the district hospital), any previous CPR training, frequent performance of resuscitation (>1/month), profession,

pre-course BLS cognitive score of ≥84% (AHA Course passing criteria), needing any remediation after training, and years since graduation from professional school. To assess collinearity, we conducted a bi-variable analysis of cognitive skills success and English fluency, as well as cognitive success on needing remediation and found independence between the variables.

The Q-CPR Review software program (Version 2.1.0.0, Laerdal Medical, Stavanger, Norway) was used to acquire, analyze and report manikin data from the log file. Statistical analysis was completed using the Stata-IC statistical package (Version 10.0, StataCorp, College Station, TX). Technical limitations precluded real-time quality control of CPR data collection, and quantification of skills was performed retrospectively.

The Institutional Review Board of the Botswana Ministry of Health, the Children's Hospital of Philadelphia, and the ethics boards of both participating hospitals, PMH and Athlone Hospital, approved the study protocol including consent procedures. Data collection procedures were completed in compliance with the guidelines of the Health Insurance Portability and Accountability Act (HIPAA) to ensure subject confidentiality. Informed written consent was obtained from all HCP who participated in the simulated resuscitation attempts.

3. Results

From January to June 2009, of the 1412 HCP eligible for training, 215 providers were enrolled and 214 completed training (Fig. 1). Median age was 27 years, 87% were Batswana and 50% had graduated from nursing or medical school within the last 5 years (Table 1). The majority (84%) of providers reported fluency in Setswana. 53% reported English fluency and 99% reported being comfortable participating in workshops conducted in English. Notably, 14% reported speaking neither English nor Setswana at home.

On the pre-training survey of the work environment, providers most frequently reported lack of training, poor or no resuscitation equipment and medication availability as weaknesses while clinical experience and teamwork were reported as strengths (Table 1). While nearly 31% worked in acute areas and 40% reported performing resuscitation at least once a month, only 28% reported any prior formal training in CPR. At training completion, 65% of providers required additional skill remediation following the 5-h course to achieve passable CPR skills by AHA criteria (Table 1). Approximately half of those needing remediation needed additional training on either adult or infant CPR skill, and the remaining needing additional training on both skills. Conversely, 16% of providers were identified as potential instructors.

Over the course of this study, the loss to follow up was 96/214 by 3 months and 25/120 at 6 months respectively (Fig. 1). Manikin output was unable to be interpreted in 84/428 baseline assessments, 13/248 post-training assessments, 10/240 3-month assessments, or 8/190 6-month assessments.

3.1. CPR cognitive assessments

Acquisition—Mean cognitive score pre-training was 63 ± 18% and rose significantly after training (84 ± 12%, $p < 0.01$ Table 2).

Retention—Although cognitive scores decreased at 3 and 6 months, retention remained significant compared to baseline knowledge (63 ± 15% vs. 75 ± 13%, 61 ± 15% vs. 74 ± 14% $p < 0.01$ for each comparison).

3.2. CPR skills

Acquisition of Excellent CPR skills—170 providers had infant and adult manikin data available for evaluation of skills acquisition (baseline-post, Table 3). *Excellent CPR* skill acquisition was significantly increased from baseline for both the infant (32% vs. 71%, $p < 0.01$) and adult (28% vs. 48%, $p < 0.01$) resuscitation scenario. 100% of providers completing training passed by AHA criteria, but 65% required skills remediation after post training assessment to pass the course.

Retention of Excellent CPR skills at 3 months—There were 89 sets of paired data for both the infant and adult CPR skill analysis (Table 3). *Excellent* CPR skill performance remained significantly increased from baseline for both the infant (39% vs. 70%, $p < 0.01$) and adult (34% vs. 51%, $p = 0.02$) resuscitation scenario.

Retention of Excellent CPR skills at 6 months—There were 72 sets of paired data for the infant CPR skill and 73 sets of paired data for the adult (Table 3). Excellent CPR skill performance remained significantly increased from baseline for infant (38% vs. 67%, $p < 0.01$), became non-significant for the adult resuscitation scenario (30% vs. 37%, $p = 0.5$).

Factors Impacting CPR Skill—In the multivariable analysis (Table 4), the adjusted odds ratio of performing Excellent CPR was significant for both infant and adult scenarios immediately after training (infant aOR: 3.4, 95%CI 2.2–5.4; adult aOR: 2.1, 95%CI 1.3–3.5) and at 3 months (infant aOR: 3.8, 95%CI 2.3–6.5; adult aOR: 2.1, 95%CI 1.3–3.5). At 6 months, the adjusted odds ratio of Excellent CPR was significant for the infant but not the adult scenario (infant aOR: 3.6, 95%CI 2.1–6.3; adult aOR: 1.4, 95%CI 0.8–2.5). Compared to traditional instruction methods, neither Limited Instruction with Feedback Manikin nor SDL method was associated with a significant odds ratio of performing Excellent CPR for either the infant or adult simulated resuscitation. Achieving a passing cognitive score and not needing any CPR skill remediation immediately after initial training was significantly associated with Excellent CPR skills (Table 4). Bi-variable analysis found independence between the cognitive success (MCQ > 84%) and English fluency, as well as between cognitive success on needing remediation.

In an exploratory analysis, missing data (lost to follow-up or not interpretable) appears to have occurred at random as there were similar training success and skill retention rates prior to drop-out in participants not completing all sessions compared to those who completed all training.

4. Discussion

Hospital-based HCP's at baseline report only 28% prior formal CPR training, and baseline cognitive knowledge and skills before training were poor. Acquisition of knowledge and CPR skills following initial training using standard or modified programs was good, and 100% reached acquisition of CPR skill competence on the day of training, however 65% required remediation prior to achieving minimal skill competence. Excellent infant CPR skills were over 3 times more likely to be performed immediately after training as well as at 3 months and 6 months compared to baseline performance before training. Excellent adult CPR skills were twice as likely to be performed after training and retained for 3 months, but retention did not persist to 6 months for adult CPR skills. Manikin-feedback with limited instructor and self-directed learning had similar acquisition and retention rates of Excellent CPR compared to traditional instructor led classes.

Healthcare providers in this study significantly retained both knowledge and skills for at least 3 months. This is different than previously reported CPR training literature from developed countries [26,28,35–39]. Rates of CPR knowledge and skill retention were similar to our previous study in a resource-rich, in-hospital environment examining low-dose, high-frequency CPR training, but providers in this study retained skills *without retraining* [21]. Almost 40% of Motswana providers in our study resuscitate patients on a *monthly* basis. Providers may have retained skills because performing resuscitation is not a rare event in the hospitals we studied. In Korea, Na et al. reported a *decrease* in hands-off time between medical interns at a tertiary hospital evaluated 6 months and 12 months after initial CPR training [18]. These findings may suggest that in environments where resuscitation is more frequent, training could be focused on skills not frequently used, new science updates, and overcoming barriers to success.

Interestingly, novel training with feedback was not inferior to traditional training. Self-Directed Learning was not intended for the novice learner, yet in this environment both SDL and a student: instructor ratio of 18:1 demonstrated significant CPR knowledge and skill acquisition and retention. The use of feedback manikins may be more reliable and equally cost-effective than developing and maintaining a large training infrastructure in resource limited settings. When personnel are the limited resource, investment in a separate instructor core may detract from optimal staffing of clinical areas, or make training inconsistent when clinical duties take priority. At this time, it is unclear whether current training equipment is robust enough to be maintained without an instructor core. Training should be cost effective, and educational technologies that are low cost but effective may significantly increase existing health capacity of resource-limited settings.

Overall skills acquisition immediately following training were still less than optimal, but not worse than previously reported training outcomes for novice trainees in developed countries [36,37,40–43]. Although providers demonstrated improvement in cognitive and psychomotor skills, standard AHA training was difficult for this novice trained, frequently resuscitating group, and most required remediation (both cognitive and psychomotor skills). This may be due to language, new to experiential/adult learning principles, and/or inadequate local contextualization of the course. English fluency was only 53%, (lower than expected as it is the national language), but in the multivariate analysis, it did not impact training. This may explain why self-directed learning, where dependence on conversational English is less than traditional instruction, may have done better than expected. It may be that skills acquisition was hampered by inadequate orientation to feedback training. Providers also may not have previously taken a hands-on course, and were more accustomed to didactic learning techniques.

5. Limitations

This was a training study, with outcomes of cognitive assessment and CPR skills, and was not linked to patient outcomes. Our study may not be representative of eligible staff's CPR skills due to selection bias of convenience sampling. A significant training effect may have been due to a low baseline prior to training. While this is the first study to document CPR skills acquisition and retention quantitatively in a resource-limited setting, it is unclear if the novel training strategies utilized would be robust over time. Additionally, we had a significant number of providers lost to follow up and loss of interpretable data (quantitative manikin data was analyzed retrospectively). A sensitivity analysis demonstrated no significant difference in rate of Excellent CPR after training between those with or without interpretable data at 3 and 6 months. We did not attempt to minimize Hawthorne effect for this initial study. Finally, there may have been other psychomotor skills/student

characteristics not captured by knowledge, skill testing or provider self-report that impact training.

6. Conclusions

Hospital providers in resource-limited settings resuscitate frequently but report low frequency of formal CPR training. They can acquire Excellent CPR in both infant and adult skills using existing AHA BLS training courses, and these CPR skills are retained at 3 months. Our CPR training program often required significant additional remediation to train providers successfully. Novel techniques with increased student: instructor ratio and self-directed training combined with automated feedback manikins were not inferior to instructor led training without manikin feedback. Cost-effective training strategies and devices should be developed to fill the resuscitation-training gap for HCP that exists in resource-limited settings.

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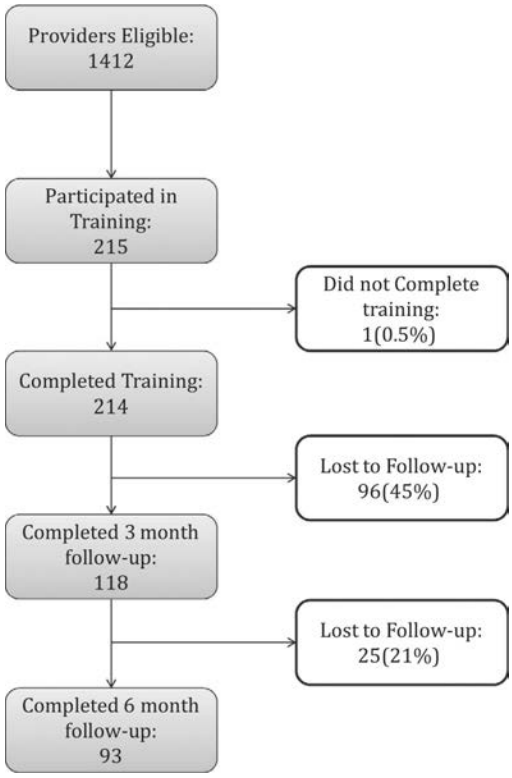

Fig. 1.
Utstein Diagram.

Table 1

Cohort description.

N	215	Resuscitation preparedness	
Age, years median [IQR]	27 [23, 33]	Training and education	
Nationality		Viewed as strength	31 (14%)
Motswana	188 (87%)	Viewed as weakness	80 (37%)
African, Non-Motswana	22 (10%)	Equipment/medications	
Non-African	5 (2%)	Viewed as strength	44 (20%)
Female	156 (73%)	Viewed as weakness	94 (44%)
English fluency	114 (53%)	Staff/teamwork	
Setswana fluency	181 (84%)	Viewed as strength	91 (42%)
Speak English at work, *n* (%)	140 (65%)	Viewed as weakness	12 (6%)
Speak English at home, *n* (%)	14 (7%)	Clinical experience	
Does not use English or Setswana at home	29 (14%)	Viewed as strength	69 (32%)
Comfortable reading English, *n* (%)	213 (99%)	Viewed as Weakness	41 (19%)
Nurse	153 (71%)	Demonstrated CPR skills competence (AHA BLS course passing criteria for certification)	214 (99.5%)
Years since school graduation, median [IQR]	5 [2, 10]	Did not require remediation Required remediation	75 (35%)
Location of work ED, OR, ICU, or “more than one ward”	67 (31%)	Single skills test	71 (33%)
High frequency of resuscitation (>1/month)	84 (39%)	Both manikins	68 (32%)
Never trained in CPR	155 (72%)	Identified as Potential Instructor	35 (16%)

Table 2

Overall cognitive testing

	N	Pre		Post		3 month		6 month		*p*-Value
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Acquisition										
Pre vs. Post	210	63%	±18%	84%	±12%					<0.01
Retention										
Pre vs. 3 month	117	63%	±15%			75%	±13%			<0.01
Pre vs. 6 month	93	61%	±15%					74%	±14%	<0.01

Comparison by Sign rank.

Table 3

Incidence of providers' skill at level of excellent CPR.

	N	Pre Mean	Post Mean	3 month Mean	6 month Mean	*p*-Value
Infant CPR skill						
Acquisition						
Pre vs. Post	170	32%	71%			<0.01
Retention						
Pre vs. 3 month	89	39%		70%		<0.01
Pre vs. 6 month	72	38%			67%	<0.01
Adult CPR skill						
Acquisition						
Pre vs. Post	170	28%	48%			<0.01
Retention						
Pre vs. 3 month	89	34%		51%		0.02
Pre vs. 6 month	73	30%			37%	0.5

Comparison by McNemar's Test for paired binary data.

Table 4

Factors impacting acquisition and retention of excellent CPR.

	Infant manikin			Adult manikin		
	Adj OR	**CI**	***p*-Value**	**Adj OR**	**CI**	***p*-Value**
Excellent CPR (comparison group: pre course)						
Acquisition	3.4	2.2–5.4	<0.01	2.1	1.3–3.5	<0.01
Retention at 3 months	3.8	2.3–6.5	<0.01	2.1	1.3–3.5	<0.01
Retention at 6 months	3.6	2.1–6.3	<0.01	1.4	0.8–2.5	0.3
Instruction type (comparison group: traditional instruction)						
Limited instructor with feedback manikin	0.8	0.5–1.4	0.5	1.1	0.7–1.8	0.7
Self-directed learning	1.0	0.5–2.1	0.9	1.3	0.7–2.7	0.4
Cognitive score > 84%	2.2	1.4–3.5	<0.01	1.6	1.0–2.4	0.03
No remediation needed	1.8	1.1–3.0	0.02	2.0	1.2–3.2	0.01
English fluency	1.5	1.0–2.2	0.07	1.1	0.7–1.6	0.7
Acute medical area	0.9	0.6–1.4	0.6	1.0	0.6–1.5	0.9
Previous CPR training	0.8	0.4–1.3	0.3	0.8	0.5–1.4	0.5
High frequency of resuscitation	1.2	0.7–1.8	0.5	0.8	0.5–1.2	0.2
Profession, nurse (vs other)	0.9	0.5–1.6	0.7	0.7	0.4–1.2	0.2
Graduated > 5 years ago	1.4	0.9–2.1	0.2	1.3	0.8–2.0	0.3