Do participants retain tourniquet skills 12 or more weeks after initial hemorrhage control training?

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I certify on my honor as a student of The University of Virginia that I have neither received nor given unauthorized aid on this assignment.

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Introduction

Introduction

According to the Center for Disease Control, (CDC, 2020), trauma is the number one killer for people 1- 45 years old, and number three overall. Of all the trauma, the leading cause of death are traumatic brain injury and uncontrolled hemorrhage (Oyeniyi, 2017). Death in the battlefield, resulting from potentially survivable injuries, are mainly the result of uncontrolled hemorrhage (Eastridge, 2011). Under the Obama Administration, and in response to mass casualty events and military experiences in Iraq and Afghanistan, the Hartford Consensus Joint Committee was formed to address pre-hospital, layperson, response to life-threatening bleeding (Stop the Bleed, 2015). While the genesis of teaching hemorrhage control to layperson stems from mass shootings, the techniques learned can be applied to everyday scenarios. Remembering that trauma is the third leading cause of death in the United States, using the skills learned in hemorrhage control training can be used at everyday activities.

Purpose

America is blessed to have one of the greatest Emergency Medical Systems (EMS) in the world. However, for the rural farmer, or dazzling urbanite stuck in traffic, the time it takes for a person to exsanguinate from a traumatic amputation is quicker than EMS can respond. As Eastridge (2012) has shown, techniques for improving survivability already exists. The purpose of this paper is to describe and analyze hemorrhage control training practice.

Background

Medical advances have come about because of the realities and horrors of war. Indeed, one of the first recorded examples of the use of a tourniquet for hemorrhage control after wounding was from the Franco-Dutch War and the Battle Flanders in 1674. During the battle,

Etienne Morel, a French surgeon, used a stick to turn and tighten a constricting band (Kraugh, 2011). Pre-hospital hemorrhage control techniques continued to improve during the more recent War on Terror, in Iraq and Afghanistan.

The Civil War, is the first war in which the streamline evacuation of injured from the battlefield was performed. At the start of the Civil War removing some of the wounded took over one week. Union surgeon, Dr. Jonathan Letterman, retooled the chaotic evacuation of the wounded from the battlefield. His optimized approach saved thousands from a lingering and horrible death on the battlefield. Soldiers on both the North and the South were taught to carry a bandana style cloth with an accompanying stick, an improvised tourniquet.

World War I (WWI) raged from 1914 through 1918, resulting in terribly murderous casualties with horrific wounds. The tactics of the war caused armies pitted against each, across swaths of "no man's land." Evacuation of the injured from the battlefield was dangerous and neither a streamlined nor hurried process, where the wounded would linger on the battlefield for days. With the delay in evacuating the wounded from the battlefield, the litter bearer had come into existence. The U.S. Navy transferred the ambulance corpsmen to forward Marine Corps units. As medics, corpsmen and litter bearers were moved forward, the use of tourniquets increased. Major Blackwood, Royal Army Medical Corps, "inclined to think that tourniquets are an invention of the Evil One, and it is no exaggeration to say that many limbs have been lost by the indiscriminate use of them." (Blackwood, 2001). Major Blackwood further contends that, "More lives have been lost than were ever saved by the use of the tourniquet." The prevailing thought to control of hemorrhage was to not touch the wound unnecessarily, cover it with a sterile dressing and do not disturb the dressing until something needs to be one with the wound.

Similar to WWI, WWII produced a large number of extremity injuries and tourniquets were once again used by Soldiers and medics. Battlefield surgeons found that tourniquets were regularly used, but due to it's designed, the overall feeling that the supplied tourniquets were ineffective. Improvised tourniquets, the Soldier's belt often lost tension during application. Surgeons stated that the only reason any tourniquet should be applied is from "active spurting hemorrhage from a major artery" (Truffier, 1915). Unlike WWI, battle plans of WWII included evacuation plans for service members. For example, ships were deployed off shore during the Battle of Iwo Jima, evacuation flights were available across the channel back to England from France, and field hospitals were closer to the wounded.

The Korean War utilized innovative evacuation of patients from the battlefield through the use of the helicopter. Through the use of these helicopters, a wounded Soldier could be quickly brought from the battlefield, to a hospital, where hemorrhage control surgery was performed. With helicopters, terrain was not a barrier unlike ground evacuations that delayed advanced care. Surgeons remarked that tourniquets saved lives in Korea. The surgeons also denied seeing limbs lost due to their use.

During the Vietnam War, tourniquets were used liberally. Tourniquet use in Viet Nam were improvised, using belts, slings, shirts, gauze, and tubing, because commercially available tourniquets didn't exist. Similar to the Korean War, surgeons found that tourniquets saved lives and that limbs were not lost due to the use of tourniquets. Again, through the use of the helicopter, the wounded were quickly retrieved from the battlefield and flown to hospitals where hemorrhage control surgery occurred. However, the lessons learned with tourniquets and the saving of lives would not be utilized during the post-Vietnam era. The military would change the way wounds would be treated on the battlefield. Post-Vietnam, the training would consist of

packing, pressure dressing, direct pressure, elevate, and as an absolute last resort, a tourniquet would be applied. The tourniquet would be an improvised version as no commercially available product existed.

Desert Shield/Desert Storm was short and due to limited casualties, data was not collected to examine if the training to treat extremity wounds needed to be altered. The same concept of using an improvised tourniquet as a last resort was the gold standard. Rapid evacuation of the wounded to forward-deployed small surgical specialty units, hemorrhage control surgery, then air transport of the wounded Soldier to definitive care kept the number of deaths low.

During the current US conflicts, Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF), surgical elements are in place so that a helicopter can fly an injured military member within one hour of any location. The Golden Hour of trauma care and the platinum fifteen became the standard of evacuation and treatment for injured service members. Any place there are U.S. military, a helicopter can fly them within one hour, and most of the time much quicker, to someplace that can perform hemorrhage control surgery (Welling, 2012).

Since mid-World War II, nearly 50 percent of combat deaths have been due to a lack of hemorrhage control. Of those, about half could have been saved if timely, appropriate hemorrhage control had been available (USAMRMC, 2020). Recent data analyzed from Operation Iraq Freedom (OIF) and Operation Enduring Freedom (OEF) show improvement in combat care. Tactical Combat Casualty Care (TCCC), including the use of tourniquet guidelines (TQ) aims to improve the survivability of combat causalities (Kragh, 2011). TCCC guidelines are designed for the control of extremity hemorrhage, which is a significant cause of preventable death on the battlefield (Kragh, 2009). Eastridge et al. (2012), identified that by individuals

carrying their own tourniquets, the number of combat-related deaths, between 2005 and 2007, from extremity hemorrhage, decreased from 23.5 to 3.5 deaths per year, a decrease of 85%. In addition to the decreased death rates with the use of tourniquets, casualties had better survival rates and were less likely to go into shock (Kragh, 2008). These military research findings regarding hemorrhage control are being extrapolated for use in the civilian community.

A typical military unit operating in a war environment will have medical assets, combat medics or corpsmen, assigned with them. These individuals are trained and ready to act if injury such as if life-threatening bleeding arises. In addition, the members of that unit are taught "self-aid" or how to apply a tourniquet to one's self. In the military, medical help is always close. The military has been teaching the tasks of applying a tourniquet for many years, yet even with the high degree of familiarity the military has with the tourniquet, they are not achieving 100% correct tourniquet application. Baruch et al. (2016), identified, through studies with Israeli Defense Forces (IDF), that the more people practice, and train with the tourniquets, the better the results when applying a tourniquet.

Problem Description

Hemorrhage control knowledge gained from OIF/OEF, and findings from the Sandy Hook Elementary School shooting, October 2015, led the Obama Administration to launch its "Stop the Bleed®" initiative. Stop the Bleed® is a national program and represents a collaboration of several federal agencies, the Department of Defense, the Department of Homeland Security, and the American College of Surgeons (Stop the Bleed, 2015). Through a meeting of trauma surgeons and medical experts within the trauma community, the resulting Hartford Consensus called for new protective and response measures within the community. The

expert group focused on local response to the rising threat of mass shootings, by providing the lay community with hemorrhage control education and hands-on practice (Jacobs, 2013).

Stop the Bleed® uses a combination of didactic and hands-on training to prepare laypersons to employ hemorrhage control strategies and resources to halt life-threatening bleeding while awaiting the arrival of emergency personnel. The core tenant of the Stop the Bleed® curriculum is training and teaching the scientific underpinnings of the appropriate use of hemostatic dressing and tourniquets to laypeople. The block of instruction includes audience-appropriate didactic review of hemorrhage identification and equipment use, followed by tactile exposure and skills demonstration of a tourniquet and hemostatic dressing placement on a low-fidelity simulation mannequin.

The lay community is not readily aligned with the same resources as the Armed Forces. Mass shooter events have led to overwhelming loss and destruction in America. Those who need hemorrhage control may not be reached by police, fire, and first aid responders for prolonged periods of time. In the Armed Forces, the medic or corpsmen, in combat, respond under fire, in "non-secure" environments to provide first aid. Due to the nature of an active shooter scene in America, the area is often declared unsafe, thus, not allowing medical help to reach those who are most in need of first aid (Jacobs, 2013). For example, Goolsby, et al, (2018) identified that through pre-hospital usage of tourniquets, nine people per month, in Maryland, could have been saved from exsanguination. These findings, if generalizable, suggests that, this number equates to over 480 lives nationally per year through tourniquet use in the community. Given the training and resources, lay community members are able to provide life-saving hemorrhage control to those around them. The opportunity exists to prepare the community to respond to hemorrhage control needs in the same manner that community members have been trained to respond to

cardiac events with CPR so that they are prepared for emergency situations and poised to provide lifesaving interventions.

Review of Literature

A literature search was performed with CINAHL, OVID Medline and PubMed databases from 1 January 2000 to present; using a medical librarian to ensure the widest and most comprehensive search. The following search terms were used: “stop the bleed campaign” or “hemorrhage control” or “tourniquet” or “Operation Iraqi Freedom” and “Operation Endearing Freedom” and “tourniquet” and “hemorrhage control” or “tourniquet training” or “skills retention” or “cardiopulmonary resuscitation” and “skills retention.” Initial search results yielded 81 studies.

The review of literature inclusion criteria encompassed: 1) hemorrhage control training for laypersons: timing, modality and frequency of training, 2) prehospital hemorrhage control and associated survival rates: military and civilian, 3) layperson perceptions of ability and willingness to apply hemorrhage control, 4) use of Stop the Bleed curriculum in hemorrhage control training, 5) CPR and skills retention, 6) studies published in English only. Exclusion criteria included 1) studies that did not include hemorrhage control outcomes with laypersons, 2) hemorrhage control in surgery, 3) studies of hemorrhage control using licensed medical providers. After reviewing studies for relevancy, duplicity and those that met the inclusion criteria, twenty-one studies were included for full review. In review of the twenty-one studies, the shared characteristics among them include the pre and post hemorrhage control training and survival rates, hemorrhage control training, methods of training, and skills retention.

Prehospital Hemorrhage Control

Seven studies examined the use of prehospital hemorrhage control with the use of tourniquets. All seven studies reported that hemorrhage is the, “leading cause of potentially preventable deaths” (Beaucreux, 2018; Beekley 2008; Eastridge (2012); Kelly 2007; King 2015; Kraugh 2008; Teixeira 2018). Five studies conducted during Operation Iraqi Freedom and Enduring Freedom (Beekley 2008; Kelly 2007; King 2015; Kragh 2008), demonstrated that prehospital hemorrhage control with tourniquets, lowered the mortality on the battlefield. Eastridge (2012) found that with full implementation of tourniquet usage, mortality from peripheral-extremity hemorrhage dropped from 23.3 deaths per year to 3.5 deaths per year, a decrease of 85%. Two studies, (Beaucreux, 2018; Teixeira, 2018). Both Beaucreux and Teixeira examined tourniquet data and hemorrhage control use in the civilian sector and found that the evidence is lacking. Teixeira found that although tourniquets are underutilized in civilian prehospital settings, when they are applied, there is a 6-fold mortality reduction in patients with peripheral vascular injuries. Beaucreux conducted a retrospective study showing that only seven states have already integrated the application of tourniquet use as a standard component of emergency response care. Prehospital tourniquet usage in Texas, and North Carolina; report that prehospital tourniquet usage was relevant. When comparing late prehospital tourniquet application in Texas and North Carolina, a higher frequency of shock was evident. While most tourniquets are applied by medical staff, with the exception of terrorist attacks, by-standers and non-medical staff are applying more tourniquets in a pre-hospital setting, (Beaucreux, 2018). Military trauma knowledge acquired during the past decade is now incorporated into civilian guidelines. While all nine studies examined prehospital hemorrhage control, the findings point out that overall, dedicated (commercial), not improvised, tourniquets are a reliable intervention to control exsanguination. Additional findings from prehospital hemorrhage control studies

suggests that a commercial rather than improvised tourniquet is most reliable to control exsanguination (King, 2017).

Hemorrhage Control Methods

Seven studies used the Stop the Bleed® hemorrhage control curriculum for layperson instruction. Of these, four found lay participants with self-reported confidence post-training, (Lei, 2019; McCarty, 2019; Pasley, 2018; Ross, 2018). Lei, (2019) and Ross, et al, (2018), examined the comfort and willingness to respond to a situation requiring the use of a tourniquet. Lei, (2019), created and examined a "Stop the Bleed" training program among school nurses, med students, and researchers, to assess participants willingness to intervene in a casualty event and explore their knowledge of trauma/hemorrhage control. The participants pre-test feelings of "willingness" increased from 59% to a post-test score of 87%, $P < .05$; and the pre-test feelings of "Preparedness" increased from 18% to a post-test score of 79%, $P < .05$. Bleeding control, (b-con), may be effective tool to increase the confidence and knowledge, while empowering the participants to intervene to prevent a hemorrhagic death.

Similar studies found evidence to support b-con training to empower the lay public to respond to mass casualty situations. Ross, (2018), used a survey, prior to b-con training, to measure participants willingness to use a tourniquet in real life, 64.2% responded "Yes." Post b-con training, the participants willingness to use a tourniquet increased to 95.6%, $P < .001$. Pasley, et al, (2018), measured participants tourniquet application and confidence pre and post Stop the Bleed® training and at 30 days post b-con. The participants increased their confidence score from 2.4 pretraining to 4.7 post-training. At 30 days, participants who correctly placed a tourniquet scored their confidence level at 4.7, while those who failed to successfully employ a tourniquet scored their confidence level at 3.3. Sixty percent of the participants, at 30 days,

successfully placed a tourniquet. McCarty, et al, (2019) examined Stop the Bleed® b-con with participants who either had no previous training (control group), previous training in first-aid only and participants who had first-aid and hemorrhage control training. All participants completed b-con training. Of the 3 groups, the group that reported they had prior first-aid and hemorrhage control training and the control group demonstrated statistical significance in the ability to correctly apply a tourniquet. The group that had prior training correctly applied a tourniquet 35.8% of the time while the control group only applied a tourniquet correctly 14.4% of the time, P =0.003. McCarty et al (2019) suggests that prior hemorrhage control training is correlated with increased odds of correctly applying a tourniquet.

Incorporating a hemorrhage control program into the community, facilitates skill development and confidence to act in emergency situations. Stop the Bleed® initiatives provides structured lecture and a tactile hemorrhage control program in the community, thereby facilitating confidence to act in emergency situations. Hemorrhage control training programs are an important first step, but further research is needed to examine how the lay public best maintains confidence in their skills and confidence to act overtime.

Tourniquet Training

Two studies focused on tourniquet training to achieve hemorrhage control, (Baruch, 2016; Goralnick, 2018). Baruch, 2016, is the only research that examined the effect of frequency of training per month between two intervention groups; Triple Application Practice (TAP), the group would apply the tourniquet three times per month, and Single Application Practice (SAP) this group would apply the tourniquet once per month. After 3 months the two groups were compared. While both groups improved, the TAP group decreased mean application time by 19 seconds, P <.001, increased applied pressure by 39 mmHg, P < .001 and reduced the number of

participants who were unable to apply any pressure by 16, *P* <.017. The SAP group's application time decrease by 8 seconds, *P* <.02; applied pressure increased by 30 mmHg, *P* <.05; while participants who were unable to apply any pressure decreased by 6, *P* <.361. Under Baruch, the more often the participants interacted, trained and applied the tourniquet, the quicker, better, their times were. Both groups improved their time, however, the group that applied the tourniquet more often had a better improvement in time.

Goralnick, et al, (2018), incorporated four groups, teaching three different techniques for hemorrhage control, with one group as a control group. Immediate post training, the b-con group, which had a formal lesson in hemorrhage control, had a higher proportion of correct tourniquet application, 87.7%, compared to the control group which had 16.3%, *P* <.001. Retesting of participants occurred between 3 to 9 months. As demonstrated by the retest results, skill decay occurred in the b-con group resulting in only 54.4% achieving hemorrhage control. Both of these studies point to the benefits of training, with refresher training, in order to best prepare laypersons in hemorrhage control.

Skills Retention

The primary outcome that was measured within my study was skills retention. There are currently no studies that address how quickly skill retention in tourniquet training degrades and no guidelines on how frequently hemorrhage control training should be conducted to maintain tourniquet application proficiency. Riggs (2019) studied skills retention in cardiopulmonary resuscitation (CPR) with a determination that when performing one skill, compressions, the rate and depth of compressions were retained at 2, 4 ½, and 6 months. However, when compression was combined with a song-instruction group, the skills were retained for 6 months. When a second skill was added, ventilation, to compression, the proportion of participants with correct

compression-ventilation ratio decreased until 3 months, then plateaued from 3 to 6 months. Participants who had previous CPR instruction performed correct compression, (25.6% P = 0.0058), ventilation, (22.3% P = 0.0038), and correct compression-ventilation ratios $P < .0001$. Garcia-Jorda, et al, (2018), assessed healthcare providers over one year, with three different time points, and demonstrated that CPR skills and knowledge deteriorate if not used or refreshed regularly. Chest compression skills degraded from baseline the further out from the initial training. Regular, short rolling refresher training sessions may help decrease skill decay. The literature related to hemorrhage control demonstrates marked improvement in confidence of the lay public to respond to emergency situations; however, there is a paucity of literature on how best to provide training to ensure skills retention over time.

Design and Methods

Project Aim

This project evaluated tourniquet skill retention in laypeople after hemorrhage control training. Laypeople participated in hemorrhage control training, then immediately post hemorrhage control training, the primary investigator (PI) and trained observers measured the time (T_1) it takes to achieve hemorrhage control, with a tourniquet. Following initial training and measurement, with the passage of 12 or more weeks post hemorrhage control training, time to hemorrhage control was remeasured (T_2). T_2 included the time it took to apply a tourniquet, without refresher training, and achieve hemorrhage control as measured by skill demonstration with a CAT on a simulated human extremity. The primary goal was to analyze the difference between T_1 and T_2 as a measurement of tourniquet skill retention.

Theoretical Framework

Knowles' (1968) Adult Learning Theory guided this study. There are four principles of Knowles' theory; the first being that adults need to know why they need to learn. Thus, teaching the evidence of trauma and how hemorrhage control can save lives is an objective of hemorrhage control training. The second principle is that adults learn experientially. A vital aspect of a successful hemorrhage control class was allowing the participants to work with equipment, allowing them to experiment, fail, and then retry was intentionally facilitated as a strategy to cement the learning. The third principle states that adults learn through problem-solving. During the hands-on portion of the training, the PI created a scenario to allow the adult participants practice problem-solving. Last, the fourth principle cites that adults learn best when the topic is of immediate value. To emphasize the value of the training, the PI noted statistics such as trauma is the leading cause of loss of life age 1- 45 years. This statistic matched the assumed demographics of the participants and mirrored the cohorts of individuals who have been bystanders at many of the tragic events around the United States. With recent tragic events, the desire was to target demographics that matched the demographics of those involved in these events.

Protection of Human Subjects

Approval of this study protocol was obtained from the University's Institutional Review Board. Consent was obtained prior to collecting of data. No participant specific identifiers were collected. Participants T_1 and T_2 data was linked by the last five digits of their phone number as supplied by the individual. Individuals who did not consent were eligible for hemorrhage control training without the assessment components. At any time, participants were able to withdraw from the study and upon request, their data destroyed.

Methods

Design, Setting, and Participants

This study incorporated a prospective quasi-experimental design with two groups measured at two different time periods. Using two groups allowed me to compare similar groups, that received the same hemorrhage control training. The groups were separated by the course of study of the participants. The purpose is to gain additional information about hemorrhage control skill retention in order to contribute to recommendations about tourniquet re-training practices. Measuring participant's ability to apply a tourniquet included data collection of time to application, the distance of the tourniquet from the wound, and success or failure in achieving hemorrhage control.

The University's Institutional Review Board for Social & Behavioral Sciences approved this study (Protocol Number: 2886) for implementation from November 2019 to February 2020. Investigators and observers included prior instructors in the Department of Defense's Tactical Combat Casualty Care (TCCC) and hemorrhage control instructors. All observers completed structured training with the PI to ensure inter-rater reliability in scoring of the outcome metrics. The PI recruited participants through a convenience sample, from the University's ROTC cadets, baccalaureate students, post baccalaureate students and laypersons. Recruitment efforts included group emails and group face-to-face introductions to the study plan. All recruitment was performed by the PI. Inclusion criteria included those who are 18 years of age or older. All genders, ethnicities and educational levels were included. Recruitment took place in and around a university community. The intervention and evaluation components took place within a dedicated classroom on campus in a location convenient to the student population.

Study Protocol

Participants self-identified into one of two groups based upon academic program of study and convenience to hemorrhage control instruction. Both groups were given the same hemorrhage control training, Stop the Bleed®, consisting of both the didactic and hands-on portion before testing. Group A was given a 3-hour block to receive the didactic training, hands-on training, and then testing. One hour was given for interactive didactic training, then the participants moved to the hands-on training, where they practice direct pressure, bandages, and tourniquet application. Group A was given as much time as they needed to practice and prepare for testing. Group A only had to focus on the hemorrhage control training and no additional skills were taught. Group B was allowed a 2-hour block of time for their training. Group B was taught hemorrhage control and two other skills from TCCC; needle decompression and airway management. Group B was given the same 1-hour didactic training, but mixed the other skills and testing with the last 60 minutes. Group B had less time to practice hemorrhage control training, prior to testing.

Participants, when they felt ready to test, were assigned a space with a designated observer for a one-on-one assessment. The participant was given a scenario, stood 10 feet away from a thigh mannequin (a simulated trauma leg with an above the knee amputation), with an opened Combat Application Tourniquet (CAT) tourniquet placed next to the mannequin. The mannequin was fixed to the table. A notification to start was given by the observer to the participants to begin application of the tourniquet and the timing initiated. The participants applied a CAT tourniquet until they indicated completion, at which time the observer stopped the timer. Following tourniquet application, the participant left the testing area. The observer recorded whether or not the participant applied the tourniquet appropriately and recoded the time to place the tourniquet, using seconds as the metric of time. The appropriateness of the

placement was determined by correct anatomical location, adequate tightness, and properly securing the CAT windlass and straps. Adequate tightness was determined using a previously tested technique; a combination of the tourniquet indenting the mannequin's skin, and an observer unable to slide their finger between the tourniquet and mannequin (Goolsby, 2015). If the participant did not apply the tourniquet appropriately, the observer documented the reasons for failure. No feedback was given to the participant. No additional attempts were provided.

Questionnaire

Prior to the initial testing participants completed a pre-event questionnaire (Appendix 1). A PI-developed questionnaire was used to capture participant demographics, medical experience and training, history of military service, and any prior experience with tourniquet training. An additional PI-developed questionnaire was used at T_2 (Appendix 2) asking if the participants, since initial training, had trained with a tourniquet, applied a tourniquet on a real victim or if they had physical, or mental, changes that preclude them from applying a tourniquet. Both questionnaires were provided in paper form and participants independently completed the documents. All documents were immediately secured by PI to maintain confidentiality. Questionnaires were later linked for comparison using a unique identifier generated by the participant.

Training

The Stop the Bleed® curriculum served as the foundation of the hemorrhage control training. Hemorrhage control training consisted of lecture followed by hands-on skills training. Participants were taught how to identify the location of life-threatening bleeding and apply pressure, pack a wound, and apply a tourniquet. Stop the Bleed® materials included the standard training kit: a simulated appendage, gauze, and other material for packing a wound, and CAT

tourniquets. There was one instructor for every eight students. To maintain validity, all instructors received the same training to reduce variability. During training, all instructors were told that successful application consisted of correct indentation of the tourniquet against the mannequin limb and the inability to slide 2 fingers under the tourniquet. If there was any doubt while testing, a 3rd instructor came in blinded to the other's interpretation and provided their assessment of the application. To reduce further variability, all of the clinical scenarios used in the training and assessment were the same.

Outcomes

The primary outcome measured was the difference between the two times. T_1 was captured immediately post hemorrhage control training, as an indicator of skill retention. T_2 was obtained approximately 12 or more weeks after T_1. Additionally, participant demographic and experiential data was collected through a PI-developed questionnaire. The aim of the questionnaire was to gain insights into factors which may influence skill retention. All data was collected at both T_1 and at T_2. These measures were obtained through direct observation of the placement of the tourniquet on the hemorrhage control simulation device and questionnaires.

Material

Material needed for the training intervention and the evaluations included the standard Stop the Bleed® training components, questionnaires, a timer, a Combat Application Tourniquet (CAT) and a simulated trauma leg, for tourniquet application. The simulated trauma leg was loaned from Dr. Craig Goolsby, Uniformed Services University of the Health Sciences (USUHS), Vice Chair, Education, USU Military and Emergency Medicine; Science Director, National Center for Disaster Medicine & Public Health. The CAT, (Composite Resources, Rock

Hill, SC) is the United States Armed Forces standard issue tourniquet for controlling limb bleeding. The CAT is 38-mm-wide light weight (~60g) tourniquet. It uses a hook-and-loop fastener and a buckle to fit a wide range of limb sizes, combined with a windlass system. The windlass uses a free-moving internal band to provide circumferential pressure to the limb. Once tightened, it is then locked in place with a clip.

The mannequin is a mold representing a right thigh with a traumatic above the knee amputation (AKA), It is made with a rubber like material giving a human skin-like texture. The design is so that laypersons are exposed to a bare thigh with clear markings indicating where the trauma occurred and thus clearly indicating where a tourniquet is required for placement. There is no fluid, or blood, flowing from the trainer, instead, bleeding is simulated.

Measures

Both questionnaire data and skill performance outcome data were collected at T_1 and T_2. Demographic data included the following elements: age, gender, ethnicity, educational level, prior healthcare training and prior hemorrhage control experience. Outcome data captured by the observers included; time to apply tourniquet, as measured in seconds, the distance from the proximal edge of the wound to the windlass in inches, and successful hemorrhage control as measured by the observer to include: time to hemorrhage control as measured in seconds, and success of application as measured using proximity to the wound, indentation by the tourniquet, and the inability to place to two fingers under the tourniquet.

Follow up Evaluation

After the hemorrhage control training and initial T_1 assessment, the participants were notified through standard email mechanisms of their 12-week window and location for the

reassessment of skills. The T_2 scenario and assessment method were identical to the baseline assessment. No retraining occurred before the T_2 scenario assessment.

Evaluation Simulation scenario development and characteristics

Hemorrhage control is the leading cause of preventable death in the civilian world and on the battlefield. Identifying and applying proper hemorrhage control techniques has the possibility to stem life-threatening bleeding. After participation in hemorrhage control training, using the Stop the Bleed® program, individuals were asked to participate in the study. Interested individuals underwent the verbal consent process. Participants were asked to complete a questionnaire -- and were briefed on the scenario before skill assessment, promoting an environment to ask questions. In each testing room, an observer read the scenario. A mannequin, with visible AKA was present and a CAT tourniquet provided. The same process occurred for T_1 and T_2.

Simulation design characteristics

The hands-on portion of the Stop the Bleed training was developed based on Knowles adult learner framework. ***Objectives.*** The primary objective for the layperson was to retain tourniquet application skills.

Fidelity. Fidelity of the simulation was used throughout by utilization of the simulated right thigh tourniquet trainer mannequin and the CAT. This mannequin allowed for real-time interaction with the use of the CAT for hemorrhage control. Lifelike conditions were to be simulated, in order to avoid the possibility of causing increased levels of stress, impacting the layperson’s ability to apply the CAT.

Complexity. The condition of the simulated patient was such that the participant did not require assessing the patient, interrupting labs or radiographs, but only required an application of a CAT and establishment of hemorrhage control.

Cues. Various participant support was available during instruction. Pre-briefing occurred before the start of the assessment. An environment of learning was established, with opportunities for clarification and questions.

The simulated patient's extremity was in obvious distress, prompting immediate intervention.

Data Analysis

All data was immediately entered into a password-protected database on a secure server. Descriptive statistics were run on all demographic data, and regression analysis was computed with outcome measures as appropriate. Mann Whitney-U statistical analysis was calculated to determine time changes betweenT_1 and T_2 between Group A and Group B.

Results

There were 114 participants who received hemorrhage control training prior to assessment at the T_1 interval. Of the 114 participants, five did not want to participate in the research, leaving 109 who participated in T_1 assessments. At T_2, 27 participants returned for subsequent assessments (Figure 2). Of the 109 participants who completed the initial assessment 27 participants completed the initial and secondary evaluation. These 27 participants are the focus of the statistical analysis. Of the 27 participants, the majority were male (63%). The mean age was 21 and the mean years of education was 15. Through the questionnaires, data on prior healthcare training via self-identification was collected, which included first-aid training, life-guard, military training, and CPR. The majority self-identified as having some form or prior

healthcare training (77%) but 63% had no prior hemorrhage control training and 66% had no prior tourniquet use training.

The 27 participants were further subdivided into two groups based upon programs of academic study and designated Group A and Group B (Table 2). Demographic analysis was performed on these subgroups. Prior healthcare training between the two groups differed in that all 12 participants for Group A had prior training while in Group B only nine of 15 participants had prior healthcare training (Table 2).

For all 27 participants, the median between T_1 and T_2 was reduced by approximately 10 seconds (Table 4). When comparing those with self-identified healthcare training with those who self-identified as not having any prior healthcare training, those with prior training reduced their tourniquet application time by approximately 7 seconds. Those who didn't claim any prior training increased their times by approximately 13.5 seconds, performing worse from T_1 to T_2 (Table 5).

With respect to assessment, at T_1, Group A had a mean tourniquet application time of 35.3 seconds and a median time of 32.7 seconds, and with T_2, Group A's mean time was 26.4 and median time was 24.2 seconds (Table 4). Group B's T_1 mean was 57.9 seconds and median time was 53.5 seconds while T_2 the mean was 77.6 and the median was 58.3 seconds (Figure 1 & 2). Group B had numerous outliers with times over 180 seconds (Table 4). Comparing Group A's and Group B's overall time difference, there was no statistically significant difference (p = 0.138). However, Group A demonstrates clinical significance in terms of faster time than Group B (Table 1). Faster time equates with less blood loss.

Discussion

Laypeople are often first on the scene to many medical emergencies, including victims with life-threatening hemorrhage. Due to the results of Sandy Hook Elementary School tragedy, the Hartford Consensus recommended teaching laypeople to learn how to properly, and safely, intervene to control life-threatening hemorrhage (Stop the Bleed, 2015). Teaching community members hemorrhage control is an important step to improving initial trauma care. The focus of this study was to understand hemorrhage control skill retention overtime among community participants.

This study replicated the approach used by Riggs (2019) to examine skills degradation with laypeople and cardiopulmonary resuscitation (CPR). Riggs study included two groups in which one group only had one skill to learn versus a second group that had more than one skill. The second group's skill degraded quickly after initial training. Based on the comparison of Group A and Group B performance metrics, this hemorrhage control study had similar findings between groups. This is a unique finding because it is one of the first to explore tourniquet training retention and it demonstrates a potentially longer time frame of skill retention than demonstrated in the CPR retention literature. During hemorrhage control training, focusing on teaching one skill in hemorrhage control, and applying those skills soon after initial training appears to have reinforced adult learners skill acquisition and contributed to immediate application of learning.

Group A had approximately 12 participants per class and was afforded a 3-hour block of time to learn hemorrhage control and train with equipment until the participant felt ready to test. Group A's hemorrhage control didactic portion was approximately one hour, while the training with equipment, was in a second classroom and lasted approximately another one hour. The last hour was available if more training was needed before testing. Group A appears to have retained

skills and reduced tourniquet application time. Conversely, Group B had 15 participants attend a two-hour block to learn hemorrhage control, pneumothorax needle decompression, airway management in trauma and tourniquet application measurement. Group B was given the same didactic lecture in less than one-hour, and then each participant was given 15 minutes to practice each skill and participate in tourniquet application testing. Group B did not seem to retain skills as readily as Group A. Group B was also slower to apply the tourniquet than Group A at both T_1 and T_2. These findings suggest a benefit of focused training sessions with ample hands-on learning experiences as potential elements that support tourniquet skill retention over time.

The most common reason for increased tourniquet application time was that the participant attempted to place the tourniquet on the simulator inside out, or wrong side towards the patient. In other words, instead of the shiny side of the tourniquet being placed towards the skin, the participant would place the shiny side away from the skin. In this manner, the tourniquet cannot be secured through the buckle, leading to failure to achieve hemorrhage control. The most common reason for failure to achieve hemorrhage control was that the tourniquet was too loose. Participants placed the tourniquet approximately five inches proximate to the wound. Group A was able to improve hemorrhage control measures from T_1 to T_2, while Group B decreased hemorrhage control measures over the same time (Table 6).

Furthermore, additional prior healthcare training may be a marker that enhances the likelihood of tourniquet skill retention and successful tourniquet application. Prior healthcare training was self-identified as training in first-aid, CPR, life guard or military training. Given that 100% of Group A participants achieved hemorrhage control, while 80% of Group B achieved hemorrhage control, the benefits of prior healthcare training may influence effectiveness of tourniquet application at T_2. With respect to the 20% of the Group B participants

who did not achieve hemorrhage control, the main reason was failure to correctly apply the tourniquet, which led to insufficient pressure on the tourniquet on the mannequin limb. Again, if Group B training had allotted for more dedicated time, perhaps, the outcome would be different. Exsanguination is a major, which is why we teach hemorrhage control. Depending on the location of the wound, a victim will exsanguinate quicker than in other locations. Each second that it takes to place a tourniquet, equals blood loss. The quicker a participant can place a tourniquet, the less blood loss by the victim**.**

Strengths and Limitations

This study included several strengths and limitations. The strengths were reflected in the methodology. The sample population of participants reflected the age range of individuals who have been frequent bystanders and victims of the majority of mass casualty events with life-threatening bleed across our country. Thus, the study engaged a pertinent population in the evaluation of tourniquet skill retention. Similarly, the training and evaluation with the CAT tourniquet was reflective of one of the most commonly encountered tourniquets in use today. With one instructor, the reliability of the material presented to participants remained consistent throughout all groups. All the observers were trained and tested to establish reliability, allowing for consistent measurements. Participants were tested in a clean, climate-controlled, well lit, sterile environment, on a static simulated leg, without any of the stress of a traumatic environment. Critical thinking was taken out of the equation because the scenario was only one trauma victim, with a clear direction to apply a tourniquet. One of the main limitations of the study was the number of participants lost to follow-up. Additional limitations included a small number of participants, only one type of tourniquet and simulator were used, critical thinking

wasn't required, as the scenario was given to the participant, and no additional stressors were applied to the participant.

One hundred nine participants initially participated in the research, allowing for increased knowledge on hemorrhage control in the community. However, only 27 participants, approximately 25%, returned for follow-up testing. Increasing the follow-up rate, would allow for a more complete understanding of the skills retained. Timing of follow-up may have contributed to participant drop-out.

Conclusions

In conclusion, the results highlight a positive trend towards the ability to maintain effective tourniquet application skills beyond 12 weeks. Additionally, the findings suggest that the success of the skill retention appears to be influenced by the training methodology and the background of the participants contributes to knowledge about training. Dedicated training with ample hands-on practice time produced better participant performance. Understanding these factors may contribute to practices that improve participants learning hemorrhage control techniques.

With respect to hemorrhage control, time is a life-saving factor. The finding that skills may not only be retained but that tourniquet application time may be reduced is particularly informative. Every second saved with quicker tourniquet application equates to less blood loss. Reducing blood loss is the ultimate goal of tourniquet application. Identifying this potential trend in relation to the training process is another unique finding of this study to be highlighted.

This study builds upon the body of knowledge on the subject of tourniquet training and provides novel insights into training practices. Further studies are needed to refine these learnings. A replication of this study, with a greater number of participants would further

enhance this knowledge and advance the understanding of best practices within hemorrhage control.

Nursing Implications

The findings of this study are highly contributory to community health promotion. The results of this study contribute to the growing body of literature and provide practical data to guide recommendations for use in developing retraining guidelines for individuals taught tourniquet application. No guidelines currently exist for retraining tourniquet skills. As a result, this study will contribute to evidence that may be used to develop training criteria for military medicine. As communities continue to determine how best to train and prepare for potential life-threatening bleeding, this study provides insight that tourniquet skills may be retained beyond 12 weeks and that retraining plans may extend beyond this time frame. Nurses who teach hemorrhage control training and advice on best practices for training may use this knowledge to support community endeavors.

Products of this Scholarly Project

The project and its products will result in submission to Libra, the submission to two journals closely associated with the military, *Journal of Special Operations Medicine* and the *Journal of Military Medicine*. Also, an abstract and presentation will be provided to the Society of Federal Health Professionals.

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Appendix

Appendix 1

Hemorrhage Control Training

Pre-Event Questionnaire

Last 5 of phone number: _____

Demographics:

Age: _____

Gender: _____

Ethnicity: _____

Education: _____

Prior Hemorrhage Control Training: Y N
(Did you learn how to stop bleeding?)

If Yes, with Tourniquet? Y N
(Did it include a device to stop bleeding?)

Prior Healthcare Training exposure: Y N
If Yes, what type of training? _____
(Military, EMT, Paramedic, CPR, First Aid Training, etc…)

Appendix 2

Hemorrhage Control Training – Phase 2

Post-Event Questionnaire

Last 5 of phone number: _____

Since November's Hemorrhage Control Training:

Have you practiced with a tourniquet? Y N
If Yes, how many times? _____

Have you applied a tourniquet on a real victim? Y N
Did you achieve hemorrhage control? Y N

Have you conducted any refresher training? Y N
If Yes, What types? (On-line, Hand's on, Reading)
What type? _____

Any physical or behavioral changes that will preclude you from applying a tourniquet? Y N

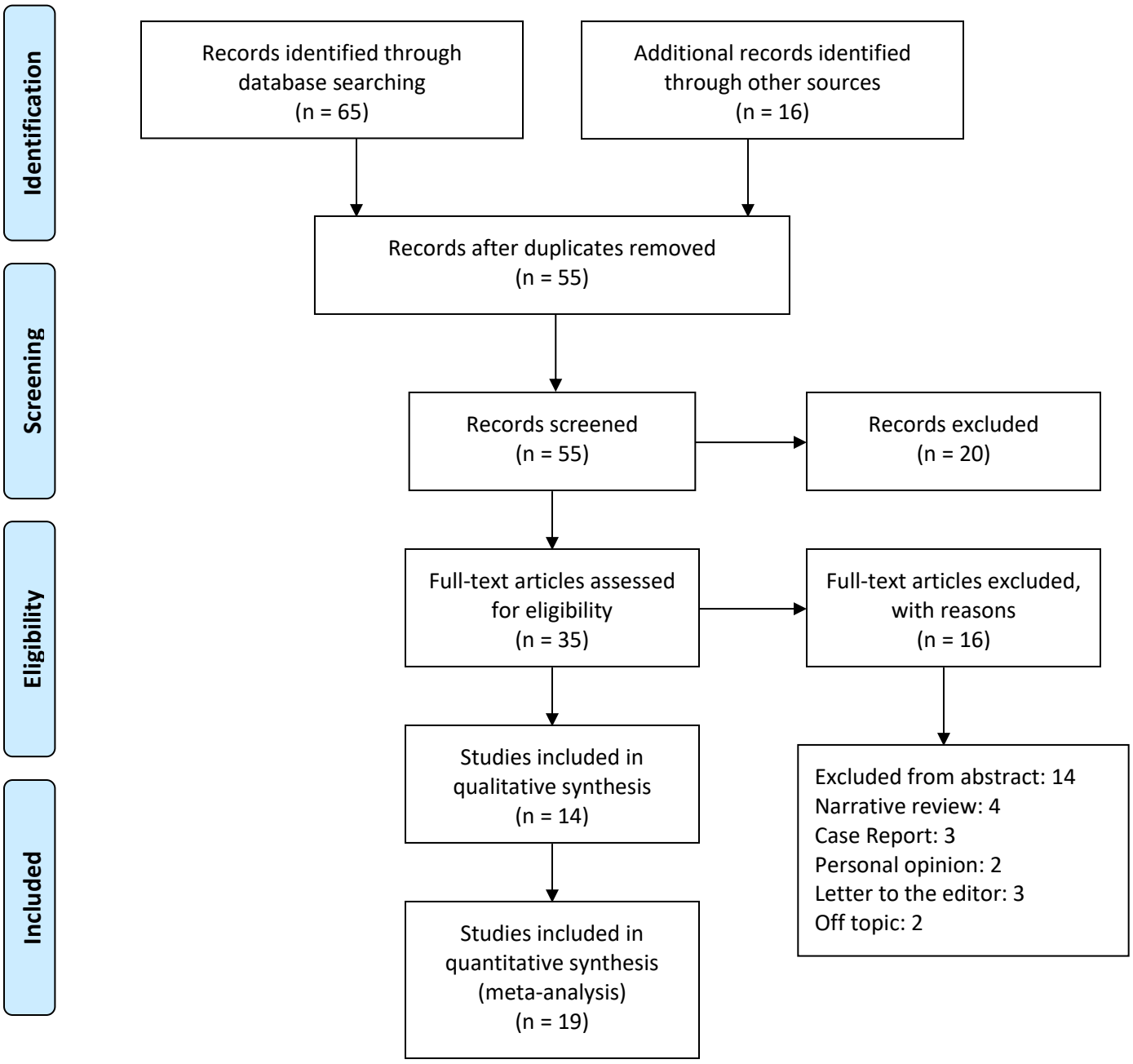
Definition of Terms

Tourniquet: A tourniquet is defined as any limb constructive device, whether improvised or commercially manufactured, used in an attempt to stop extremity bleeding (Kragh, 2008).

Hemorrhage Control: The meaningful reduction or cessation of excessive and life-threatening bleeding.

Simulation: Activities that mimic the reality of a clinical environment and are designed to demonstrate procedures, decision-making, and critical thinking through techniques such as role playing and the use of devices (Jeffries, 2005).

Stop the Bleed: is a national awareness campaign and call-to-action. Stop the Bleed is intended to cultivate grassroots efforts that encourage bystanders to become trained, equipped, and empowered to help in a bleeding emergency before professional help arrives (Stop the Bleed, 2019). The program teaches a standardized approach to hemorrhage control using didactic and hands-on training techniques, including pressure, combat gauze and tourniquet.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Screening
Eligibility
Included
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Records after duplicates removed (n = 55)
Records screened (n = 55)
Records excluded (n = 20)
Full-text articles assessed for eligibility (n = 35)
Full-text articles excluded, with reasons (n = 16)
Studies included in qualitative synthesis (n = 14)
Studies included in quantitative synthesis (meta-analysis) (n = 19)
Excluded from abstract: 14
Narrative review: 4
Case Report: 3
Personal opinion: 2
Letter to the editor: 3
Off topic: 2

Figure 1

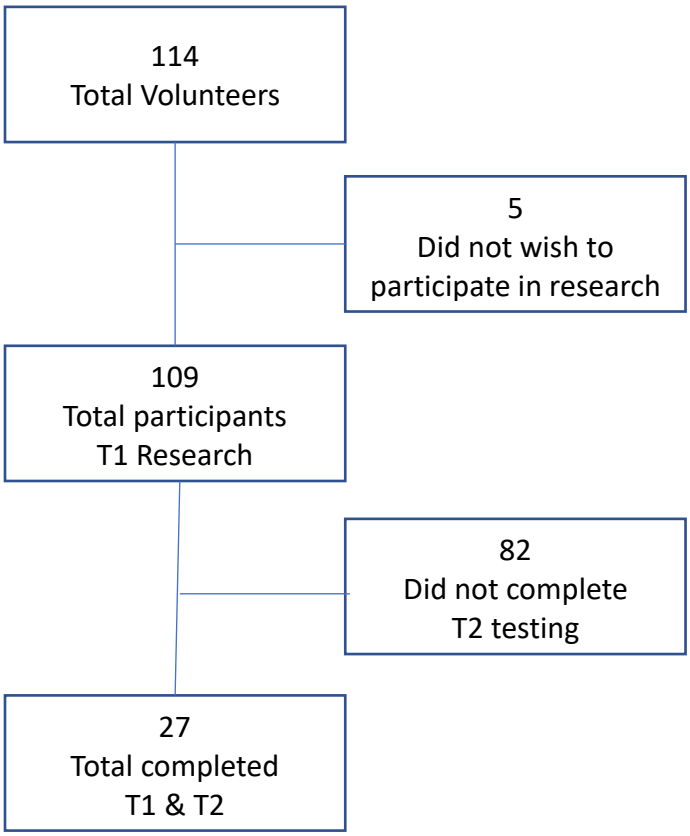
114
Total Volunteers
5
Did not wish to
participate in research
109
Total participants
T1 Research
82
Did not complete
T2 testing
27
Total completed
T1 & T2

Figure 2

Table 1

Test Statistics[a]	Time difference
Mann-Whitney U	59.000
Wilcoxon W	137.000
Z	-1.513
Asymp. Sig. (2-tailed)	.130
Exact Sig. [2*(1-tailed Sig.)]	.139[b]

$p = 0.130$ based on Mann-Whitney U test.

Table 2

Aggregate Demographics Characteristics of Participants Conducting Hemorrhage Control Training

	N	Gender		Education	Age	Prior Healthcare Trng		Prior Hemorrhage Trng		Prior Tourniquet Trng	
	Freq	Male	Female	*M*	*M*	Yes	No	Yes	No	Yes	No
Aggregate	27	17 (63.0)	10 (37.0)	15.2	21.6	21	6	10	17	9	18
Group A	12	3 (25.0)	9 (75.0)	15.4	23.3	12	0	3	9	2	10
Group B	15	14 (93.3)	1 (6.7)	15.0	20.1	9	6	7	8	7	8

Note, (%), *M*, indicates Mean.

Table 3

Self-Identified Healthcare Training

Training	N	Percentage
First-Aid	12	44.4%
CPR	16	59.3%
Lifeguard	2	7.4%
Military	2	7.4%

Table 4

Overall Participant Time Difference		Time T_1	Time T_2
N	Valid	27	27
		Time 1	Time 2
Mean		47.89	54.86
Median		44.18	34.40
Std. Deviation		21.27	48.13
Range		90.97	181.05
Minimum		19.69	12.79
Maximum		110.660	193.84

Table 5

Prior Healthcare Training Time Difference in seconds

Prior Healthcare Training	Time Difference
No	13.5450
Yes	-7.3400
Total	-6.5700

Table 6

Reasons for Failure to Achieve Hemorrhage Control

	Time	MD Inches	Indent Yes	Indent No	Indent %	2 FT Yes	2 FT No	2 FT %	HC Yes	HC No	HC %
Aggregate	T1	5.6	26	1	96.3	27	0	100	26	1	96.3
	T2	5.3	24	3	88.9	24	3	88.9	24	3	88.9
Group A	T1	5.3	11	1	91.7	12	0	100	11	1	91.7
	T2	5.1	12	0	100	12	0	100	12	0	100
Group B	T1	5.9	15	0	100	15	0	100	15	0	100
	T2	5.4	12	3	80.0	12	3	80.0	12	3	80.0

Note, MD, indicates Mean Distance, 2 FT, indicates 2 Finger Test under the Tourniquet, HC, indicates Hemorrhage Control.

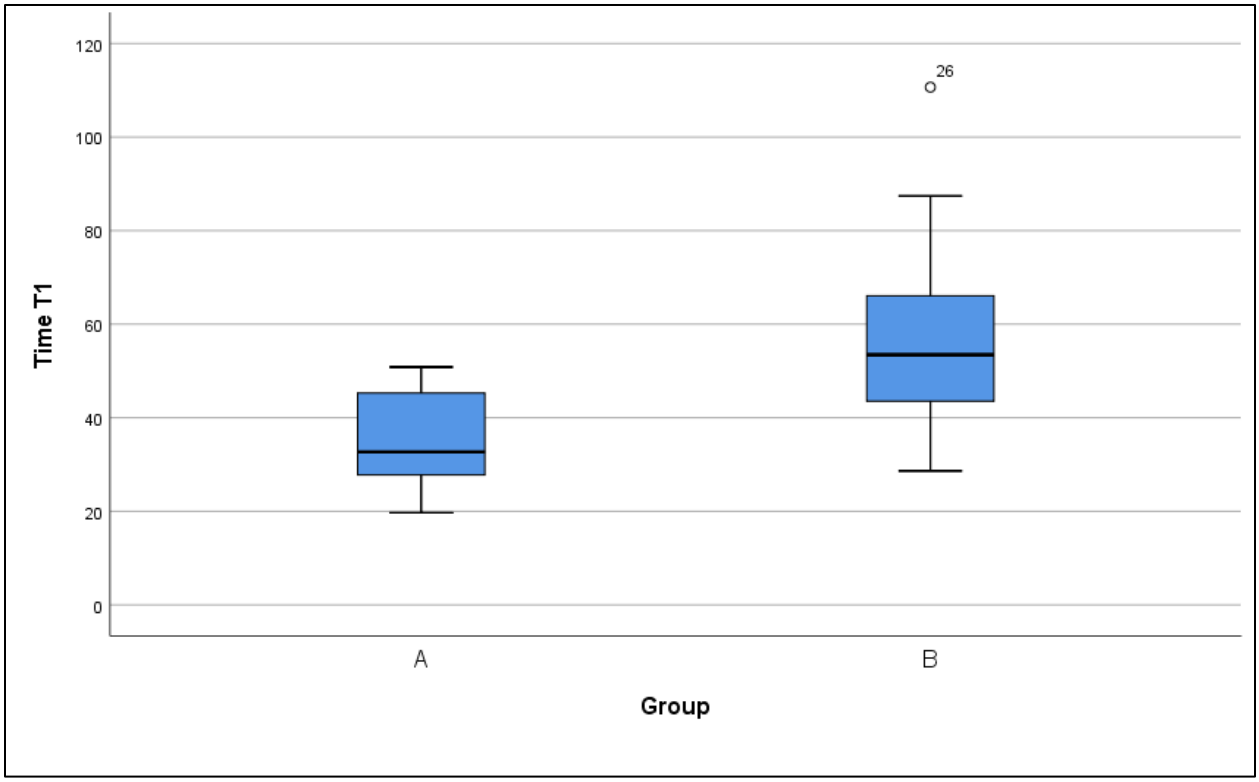

Figure 3. T_1 the tourniquet application times between Group A & B. Group A's T_1 median application time is less than Group B, with more uniform times, while Group B's T_1 median application time is slower with greater variance.

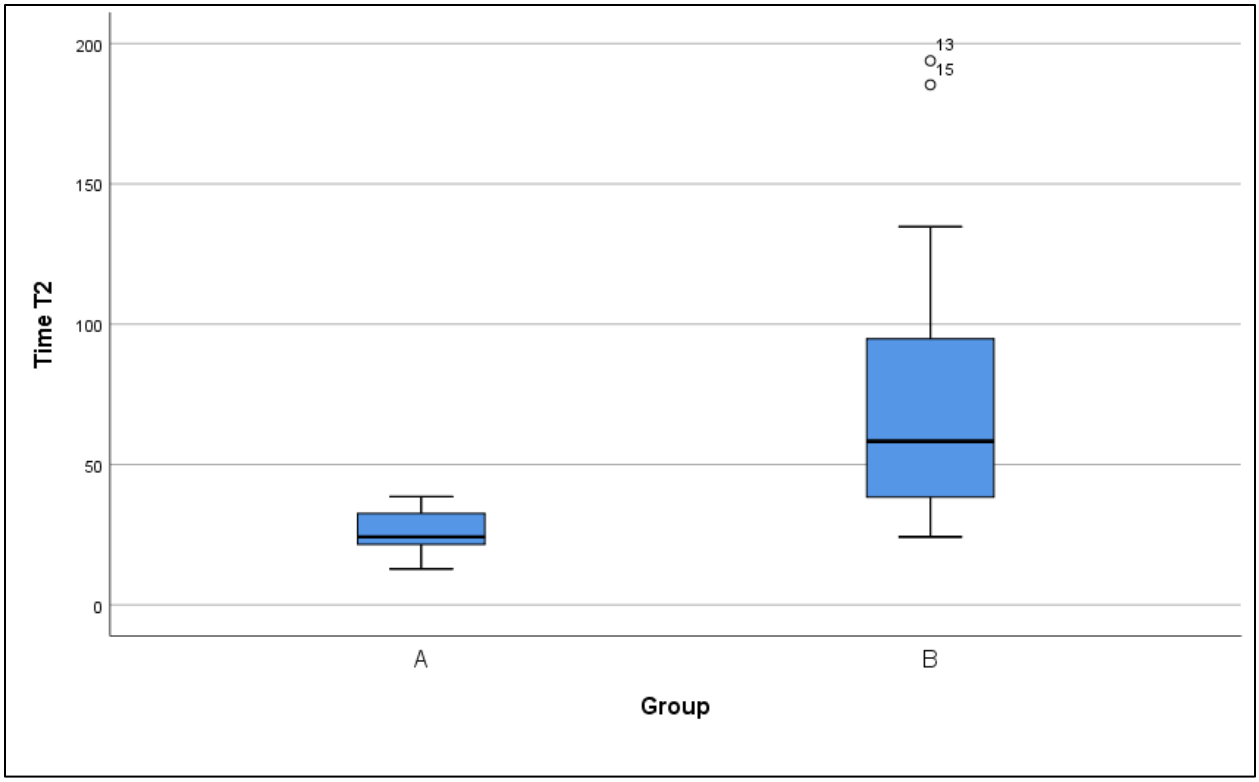

Figure 4. T_2 median tourniquet application times between Group A & B. Group A's times have decreased while simultaneously become more uniform. Group B's application times have increased, median has gotten slower, and greater outliers are present.

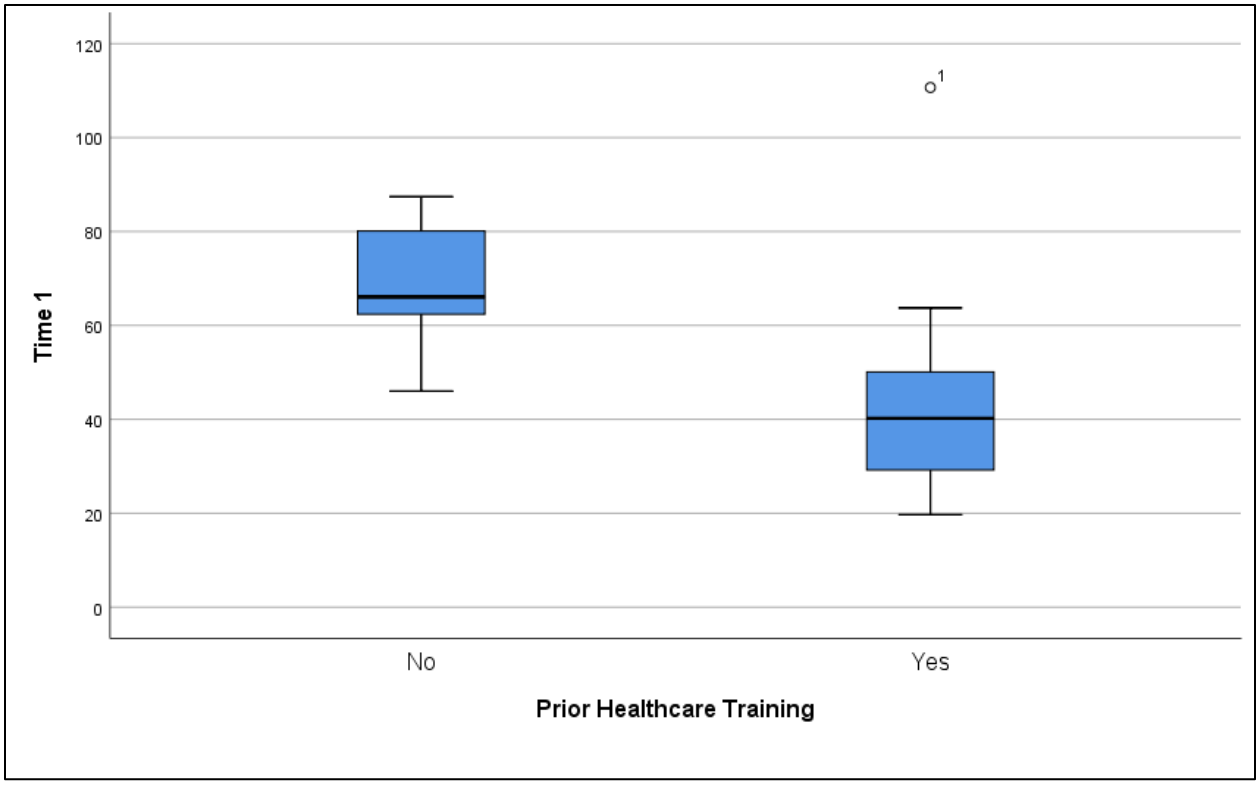

Figure 5. T_1 tourniquet application time with those with prior healthcare training. Examining the aggregate, those with prior healthcare training have quicker tourniquet application times than those without healthcare training.

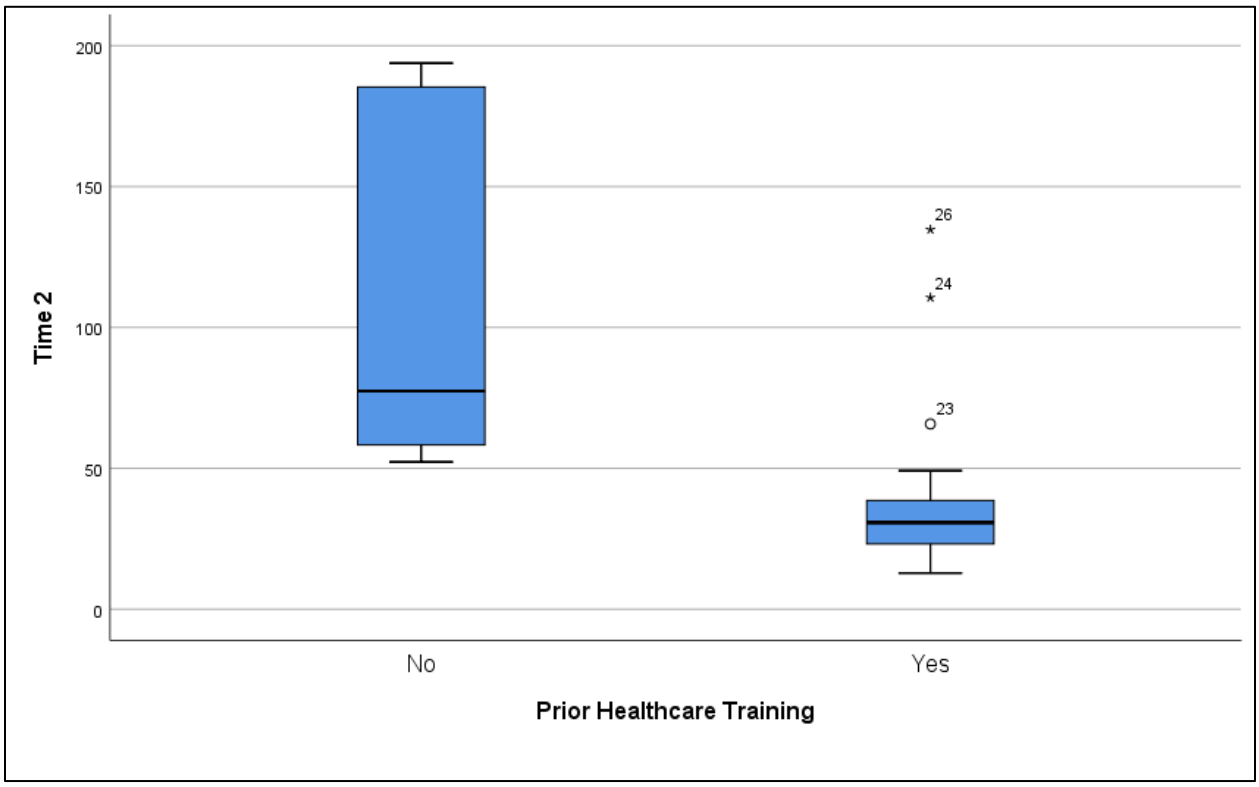

Figure 6. T_2 tourniquet application time of those with prior healthcare training. 21 participants had prior healthcare training, showing a decreased median tourniquet application time.

Manuscript

12 weeks after hemorrhage control training, do the skills remain?

Keith J Denneny

Beth Quatrara

Sarah Craig

David Martin

Introduction

According to the Center for Disease Control, (CDC, 2020), trauma is the number one killer for people 1- 45 years old, and number three overall. Of all the trauma, the leading cause of death are traumatic brain injury and uncontrolled hemorrhage (Oyeniyi, 2017). Death in the battlefield, resulting from potentially survivable injuries, are mainly the result of uncontrolled hemorrhage (Eastridge, 2011). In response to mass casualty events and military experiences in Iraq and Afghanistan, the Hartford Consensus Joint Committee was formed to address pre-hospital, layperson, response to life-threatening bleeding (Stop the Bleed, 2015). While the genesis of teaching hemorrhage control to layperson stems from mass shootings, the techniques learned can be applied to everyday scenarios. The purpose of this paper is to describe and analyze hemorrhage control training practice in laypeople.

Background

Medical advances often arise because of the realities and horrors of war. Recent data analyzed from Operation Iraq Freedom (OIF) and Operation Enduring Freedom (OEF) show improvement in combat care. Tactical Combat Casualty Care (TCCC), including the use of tourniquet guidelines (TQ), aims to improve the survivability of combat causalities (Kragh, 2011). TCCC guidelines are designed for the control of extremity hemorrhage, which is a significant cause of preventable death on the battlefield (Kragh, 2009). Eastridge et al. (2012), identified that by individuals carrying their own tourniquets, the number of combat-related deaths, between 2005 and 2007, from extremity hemorrhage, decreased from 23.5 to 3.5 deaths per year, a decrease of 85%. In addition to the decreased death rates with the use of tourniquets, casualties had better survival rates and were less likely to go into shock (Kragh, 2008). These

military research findings regarding hemorrhage control are being extrapolated for use in the civilian community.

Problem Description

Hemorrhage control knowledge gained from OIF/OEF, and findings from the Sandy Hook Elementary School shooting, led the launch of its "Stop the Bleed®" initiative. Stop the Bleed® is a national program and represents a collaboration of several federal agencies, (Stop the Bleed, 2015). Through a meeting of trauma surgeons and medical experts within the trauma community, the resulting Hartford Consensus called for new protective and response measures within the community. The expert group focused on local response to the rising threat of mass shootings, by providing the lay community with hemorrhage control education and hands-on practice (Jacobs, 2013).

Stop the Bleed® uses a combination of didactic and hands-on training to prepare laypersons to employ hemorrhage control strategies and resources to halt life-threatening bleeding while awaiting the arrival of emergency personnel. The core tenant of the Stop the Bleed® curriculum is training and teaching the appropriate use of hemostatic dressing and tourniquets to laypeople. The block of instruction includes audience-appropriate didactic review of hemorrhage identification and equipment use, followed by tactile exposure and skills demonstration of a tourniquet and hemostatic dressing placement on a low-fidelity simulation mannequin.

Given the training and resources, lay community members are able to provide life-saving hemorrhage control to those around them. The opportunity exists to prepare the community to respond to hemorrhage control needs in the same manner that community members have been

trained to respond to cardiac events with CPR so that they are prepared for emergency situations and poised to provide lifesaving interventions.

Review of Literature

An exploration of the literature identified studies focused on topics of hemorrhage control, hemorrhage control training, and skills retention.

Prehospital Hemorrhage Control

Seven studies examined the use of prehospital hemorrhage control with the use of tourniquets. All seven studies reported that hemorrhage is the, "leading cause of potentially preventable deaths" (Beaucreux, 2018; Beekley 2008; Eastridge 2012; Kelly 2007; King 2015; Kragh 2008; Teixeira 2018). Five studies conducted during Operation Iraqi Freedom and Enduring Freedom (Beekley 2008; Kelly 2007; King 2015; Kragh 2008), demonstrated that prehospital hemorrhage control with tourniquets, lowered the mortality on the battlefield. Eastridge (2012) found that with full implementation of tourniquet usage, mortality from peripheral-extremity hemorrhage dropped from 23.3 deaths per year to 3.5 deaths per year, a decrease of 85%. Two studies, (Beaucreux, 2018; Teixeira, 2018) examined tourniquet data and hemorrhage control use in the civilian sector and found that the evidence is lacking. Teixeira found that although tourniquets are underutilized in civilian prehospital settings, when they are applied, there is a 6-fold mortality reduction in patients with peripheral vascular injuries. Beaucreux conducted a retrospective study showing that only seven states have already integrated the application of tourniquet use as a standard component of emergency response care. Reports reveal that prehospital tourniquet usage was effective in reducing adverse outcomes. When comparing late prehospital tourniquet application, a higher frequency of shock was evident. While most tourniquets are applied by medical staff, with the exception of terrorist

attacks, by-standers and non-medical staff are applying more tourniquets in a pre-hospital setting, (Beaucreux, 2018). While all studies examined prehospital hemorrhage control, the findings point out that overall, dedicated (commercial), not improvised, tourniquets are a reliable intervention to control exsanguination. Additional findings from prehospital hemorrhage control studies suggest that a commercial rather than improvised tourniquet is most reliable to control exsanguination (King, 2017).

Hemorrhage Control Methods

Seven studies used the Stop the Bleed® hemorrhage control curriculum for layperson instruction. Of these, four found lay participants with self-reported confidence post-training, (Lei, 2019; McCarty, 2019; Pasley, 2018; Ross, 2018). Lei, (2019) and Ross, et al, (2018), examined the comfort and willingness to respond to a situation requiring the use of a tourniquet. Lei, (2019), created and examined a "Stop the Bleed" training program among school nurses, med students, and researchers, to assess participants willingness to intervene in a casualty event and explore their knowledge of trauma/hemorrhage control. The participants pre-test feelings of "willingness" increased from 59% to a post-test score of 87%, $P < .05$; and the pre-test feelings of "preparedness" increased from 18% to a post-test score of 79%, $P < .05$. Bleeding control, may be effective tool to increase the confidence and knowledge, while empowering the participants to intervene to prevent a hemorrhagic death.

Similar studies found evidence to support bleeding control training to empower the lay public to respond to mass casualty situations. Ross, (2018), used a survey, prior to training, to measure participants willingness to use a tourniquet in real life, 64.2% responded "Yes." Post training, the participants willingness to use a tourniquet increased to 95.6%, $P < .001$. Pasley, et al, (2018), measured participants tourniquet application and confidence pre and post Stop the

Bleed® training and at 30 days after. The participants increased their confidence score from 2.4 pretraining to 4.7 post-training. At 30 days, participants who correctly placed a tourniquet scored their confidence level at 4.7, while those who failed to successfully employ a tourniquet scored their confidence level at 3.3. Sixty percent of the participants, at 30 days, successfully placed a tourniquet. McCarty, et al, (2019) examined Stop the Bleed® with participants who either had no previous training (control group), previous training in first-aid only and participants who had first-aid and hemorrhage control training. All participants completed training. Of the 3 groups, the group that reported they had prior first-aid and hemorrhage control training and the control group demonstrated statistical significance in the ability to correctly apply a tourniquet. The group that had prior training correctly applied a tourniquet 35.8% of the time while the control group only applied a tourniquet correctly 14.4% of the time, P =0.003. McCarty et al (2019) suggests that prior hemorrhage control training is correlated with increased odds of correctly applying a tourniquet.

Incorporating a hemorrhage control program into the community, facilitates skill development and confidence to act in emergency situations. Hemorrhage control training programs are an important first step, but further research is needed to examine how the lay public maintains confidence in their skills and actions overtime.

Skills Retention

There are currently no studies that address how quickly skill retention in tourniquet training degrades and no guidelines on how frequently hemorrhage control training should be conducted to maintain tourniquet application proficiency. Riggs (2019) studied skills retention in cardiopulmonary resuscitation (CPR) with a determination that when performing one skill, compressions, the rate and depth of compressions were retained at 2, 4 ½, and 6 months.

However, when compression was combined with a song-instruction group, the skills were retained for 6 months. When a second skill was added, ventilation, to compression, the proportion of participants with correct compression-ventilation ratio decreased until 3 months, then plateaued from 3 to 6 months. Participants who had previous CPR instruction performed correct compression, (25.6% $P = 0.0058$), ventilation, (22.3% $P = 0.0038$), and correct compression-ventilation ratios $P < .0001$. Garcia-Jorda, et al, (2018), assessed healthcare providers over one year, with three different time points, and demonstrated that CPR skills and knowledge deteriorate if not used or refreshed regularly. Chest compression skills degraded from baseline the further out from the initial training. Regular, short rolling refresher training sessions may help decrease skill decay. However, there is no literature on how best to provide hemorrhage control training to ensure skills retention over time.

Design and Methods

This project evaluated tourniquet skill retention in laypeople after hemorrhage control training. Approval of this study protocol was obtained from the Institutional Review Board. Consent was obtained prior to collecting of data. This study incorporated a prospective quasi-experimental design with two groups of college students measured at two different time periods. The groups were designated by academic course of study as self-identified by the participant.

The PI recruited participants through a convenience sample, from the University's ROTC cadets, baccalaureate students, post baccalaureate students and laypersons. Recruitment efforts included group emails and group face-to-face introductions to the study plan. Inclusion criteria included those who are 18 years of age or older. All genders, ethnicities and educational levels were included.

Study Protocol

Participants were taught how to identify the location of life-threatening bleeding and apply pressure, pack a wound, and apply a tourniquet. Stop the Bleed® materials included the standard training kit: a simulated appendage, gauze, and other material for packing a wound, and CAT tourniquets. There was one instructor for every eight students. To maintain validity, all instructors received the same training to reduce variability.

Group A was given a 3-hour block to receive the didactic training, hands-on training, and then testing. One hour was given for interactive didactic training, then the participants moved to the hands-on training, where they practice direct pressure, bandages, and tourniquet application. Group A was given as much time as they needed to practice and prepare for testing. Group A only had to focus on the hemorrhage control training and no additional skills were taught. Group B was allowed a 2-hour block of time for their training. Group B was taught hemorrhage control and two other skills from Department of Defense's Tactical Combat Casualty Care (TCCC); needle decompression and airway management. Group B was given the same 1-hour didactic training, but mixed the other skills and testing with the last 60 minutes. Group B had less time to practice hemorrhage control training, prior to testing.

Participants, when they felt ready to test, were assigned a space with a designated observer for a one-on-one assessment. Investigators and observers included prior instructors in TCCC and hemorrhage control instructors. All observers completed structured training with the PI to ensure inter-rater reliability in scoring of the outcome metrics. During assessment, the participant was given a scenario, stood 10 feet away from a thigh mannequin (a simulated trauma leg with an above the knee amputation), with an opened Combat Application Tourniquet (CAT) tourniquet placed next to the mannequin. The mannequin was fixed to the table. A notification to start was given by the observer to the participants to begin application of the tourniquet and the

timing initiated. The participants applied a CAT tourniquet until they indicated completion, at which time the observer stopped the timer. This time was recorded as T_1. Following tourniquet application, the participant left the testing area. The observer recorded whether or not the participant applied the tourniquet appropriately and recoded the time to place the tourniquet, using seconds as the metric of time. The appropriateness of the placement was determined by correct anatomical location, adequate tightness, and properly securing the CAT windlass and straps. Adequate tightness was determined using a previously tested technique; a combination of the tourniquet indenting the mannequin's skin, and an observer unable to slide their finger between the tourniquet and mannequin (Goolsby, 2015). If the participant did not apply the tourniquet appropriately, the observer documented the reasons for failure. No feedback was given to the participant. No additional attempts were provided.

Follow up Evaluation

After the hemorrhage control training and initial T_1 assessment, the participants were notified through standard email mechanisms of their 12-week window and location for the reassessment of skills. The T_2 scenario and assessment method were identical to the baseline assessment. No retraining occurred before the T_2 scenario assessment.

Questionnaire

Prior to the initial testing, participants completed a pre-event questionnaire (Appendix 1). The questionnaire was PI-developed to capture participant demographics and history of experiences. An additional PI-developed questionnaire was used at T_2 (Appendix 2) asking if the participants experienced any pertinent changes since initial training. Both questionnaires were provided in paper form and participants independently completed the documents.

Questionnaires were later linked for comparison using a unique identifier generated by the participant.

Outcomes

Both questionnaire data and skill performance outcome data were collected at T_1 and T_2. The primary outcome measured was the difference between the two times. T_1 was captured immediately post hemorrhage control training, as an indicator of skill retention. T_2 was obtained approximately 12 or more weeks after T_1. Additionally, participant demographic and experiential data was collected through a PI-developed questionnaire (Figures 1 and 2). The aim of the questionnaire was to gain insights into factors which may influence skill retention. All data was collected at both T_1 and at T_2. These measures were obtained through direct observation of the placement of the tourniquet on the hemorrhage control simulation device and questionnaires.

Data Analysis

Descriptive statistics were run on all demographic data, and regression analysis was computed as appropriate. Mann Whitney-U statistical analysis was calculated to determine time changes betweenT_1 and T_2 between Group A and Group B.

Results

There were 109 students who volunteered to participate in the research and completed T_1 assessments. At T_2, 27 participants returned for subsequent assessments. Of the 109 participants who completed the initial assessment 27 participants completed the initial and secondary evaluation. These 27 participants are the focus of the statistical analysis. Of the 27 participants, the majority were male (63%). The mean age was 21 and the mean years of education was 15. Through the questionnaires, data on prior healthcare training via self-identification was collected, which included first-aid training, life-guard, military training, and CPR. The majority

self-identified as having some form or prior healthcare training (77%) but 63% had no prior hemorrhage control training and 66% had no prior tourniquet use training.

The 27 participants were further subdivided into two groups based upon programs of academic study and designated Group A and Group B (Table 2). Demographic analysis was performed on these subgroups. Prior healthcare training between the two groups differed in that all 12 participants for Group A had prior training while in Group B only nine of 15 participants had prior healthcare training (Table 2).

For all 27 participants, the median between T_1 and T_2 was reduced by approximately 10 seconds (Table 3). When comparing those with self-identified healthcare training with those who self-identified as not having any prior healthcare training, those with prior training reduced their tourniquet application time by approximately 7 seconds. Those who didn't claim any prior training increased their times by approximately 13.5 seconds, performing worse from T_1 to T_2 (Table 4).

With respect to assessment, at T_1, Group A had a mean tourniquet application time of 35.3 seconds and a median time of 32.7 seconds, and with T_2, Group A's mean time was 26.4 and median time was 24.2 seconds (Table 3). Group B's T_1 mean was 57.9 seconds and median time was 53.5 seconds while T_2 the mean was 77.6 and the median was 58.3 seconds (Figure 1 & 2). Group B had numerous outliers with times over 180 seconds (Table 3). Comparing Group A's and Group B's overall time difference, there was no statistically significant difference (p = 0.138). However, Group A demonstrates clinical significance in terms of faster time than Group B (Table 1). Faster time equates with less blood loss.

Discussion

Laypeople, particularly college-aged individuals, are often first on the scene to many medical emergencies, including victims with life-threatening hemorrhage. Teaching community members hemorrhage control is an important step to improving initial trauma care. The focus of this study was to understand hemorrhage control skill retention overtime among community participants.

This study replicated the approach used by Riggs (2019) to examine skills degradation with laypeople and cardiopulmonary resuscitation (CPR). Riggs study included two groups in which one group only had one skill to learn versus a second group that had more than one skill. The second group's skill degraded quickly after initial training. Based on the comparison of Group A and Group B performance metrics, this hemorrhage control study had similar findings between groups. This is a unique finding because it is one of the first to explore tourniquet training retention. During hemorrhage control training, focusing on teaching one skill in hemorrhage control, and applying those skills soon after initial training appears to have reinforced adult learners skill acquisition and contributed to immediate application of learning.

Group A had approximately 12 participants per class and was afforded a 3-hour block of time to learn hemorrhage control and train with equipment until the participant felt ready to test. Group A's hemorrhage control didactic portion was approximately one hour, while the training with equipment, was in a second classroom and lasted approximately another one hour. The last hour was available if more training was needed before testing. Group A appears to have retained skills and reduced tourniquet application time. Conversely, Group B had 15 participants attend a two-hour block to learn hemorrhage control, pneumothorax needle decompression, airway management in trauma and tourniquet application measurement. Group B was given the same didactic lecture in less than one-hour, and then each participant was given 15 minutes to practice

each skill and participate in tourniquet application testing. Group B did not seem to retain skills as readily as Group A. Group B was also slower to apply the tourniquet than Group A at both T_1 and T_2. These findings suggest a benefit of focused training sessions with ample hands-on learning experiences as potential elements that support tourniquet skill retention over time.

The most common reason for increased tourniquet application time was that the participant attempted to place the tourniquet on the simulator inside out, or wrong side towards the patient. In other words, instead of the shiny side of the tourniquet being placed towards the skin, the participant would place the shiny side away from the skin. In this manner, the tourniquet cannot be secured through the buckle, leading to failure to achieve hemorrhage control. The most common reason for failure to achieve hemorrhage control was that the tourniquet was too loose. Participants placed the tourniquet approximately five inches proximate to the wound. Group A was able to improve hemorrhage control measures from T_1 to T_2, while Group B decreased hemorrhage control measures over the same time (Table 5).

Furthermore, additional prior healthcare training may be a marker that enhances the likelihood of tourniquet skill retention and successful tourniquet application. Prior healthcare training was self-identified as training in first-aid, CPR, life guard or military training. Given that 100% of Group A participants achieved hemorrhage control, while 80% of Group B achieved hemorrhage control, the benefits of prior healthcare training may influence effectiveness of tourniquet application at T_2. With respect to the 20% of the Group B participants who did not achieve hemorrhage control, the main reason was failure to correctly apply the tourniquet, which led to insufficient pressure on the tourniquet on the mannequin limb. Again, if Group B training had allotted for more dedicated time, perhaps, the outcome would be different.

Strengths and Limitations

This study included several strengths and limitations. The strengths were reflected in the methodology. The sample population of participants reflected the age range of individuals who have been frequent bystanders and victims of the majority of mass casualty events with life-threatening bleed across our country. Thus, the study engaged a pertinent population in the evaluation of tourniquet skill retention. Similarly, the training and evaluation with the CAT tourniquet was reflective of one of the most commonly encountered tourniquets in use today. With one instructor, the reliability of the material presented to participants remained consistent throughout all groups. All the observers were trained and tested to establish reliability, allowing for consistent measurements. Participants were tested on a static simulated leg, without any of the stress of a traumatic environment.

One of the main limitations of the study was the number of participants lost to follow-up. Increasing the follow-up rate, would allow for a more complete understanding of the skills retained Additional limitations included a small number of participants, only one type of tourniquet and simulator were used, critical thinking wasn't required, as the scenario was given to the participant, and no additional stressors were applied to the participant.

Conclusions

In conclusion, the results highlight a positive trend towards the ability to maintain effective tourniquet application skills beyond 12 weeks. Additionally, the findings suggest that the success of the skill retention appears to be influenced by the training methodology and the background of the participants contributes to knowledge about training. Dedicated training with ample hands-on practice time produced better participant performance. Understanding these factors may contribute to practices that improve participants learning hemorrhage control techniques.

With respect to hemorrhage control, time is a life-saving factor. Every second saved with quicker tourniquet application equates to less blood loss. No guidelines currently exist for retraining tourniquet skills. As communities continue to determine how best to train and prepare for potential life-threatening bleeding, this study provides insight that tourniquet skills may be retained beyond 12 weeks and that retraining plans may extend beyond this time frame. Health care providers who teach hemorrhage control training and advice on best practices for training may use this knowledge to support community endeavors.

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Appendix

Appendix 1

Hemorrhage Control Training

Pre-Event Questionnaire

Last 5 of phone number: _____

Demographics:

Age: _____

Gender: _____

Ethnicity: _____

Education: _____

Prior Hemorrhage Control Training: Y N
(Did you learn how to stop bleeding?)

If Yes, with Tourniquet? Y N
(Did it include a device to stop bleeding?)

Prior Healthcare Training exposure: Y N
If Yes, what type of training? _____
(Military, EMT, Paramedic, CPR, First Aid Training, etc…)

Appendix 2

Hemorrhage Control Training – Time 2

Post-Event Questionnaire

Last 5 of phone number: _____

Since November's Hemorrhage Control Training:

Have you practiced with a tourniquet? Y N
If Yes, how many times? _____

Have you applied a tourniquet on a real victim? Y N
Did you achieve hemorrhage control? Y N

Have you conducted any refresher training? Y N
If Yes, What types? (On-line, Hand's on, Reading)
What type? _____

Any physical or behavioral changes that will preclude you from applying a tourniquet? Y N

Table 1

Test Statistics[a]	Time difference
Mann-Whitney U	59.000
Wilcoxon W	137.000
Z	-1.513
Asymp. Sig. (2-tailed)	.130
Exact Sig. [2*(1-tailed Sig.)]	.139[b]

$p = 0.05$ based on Mann-Whitney U test.

Table 2

Aggregate Demographics Characteristics of Participants Conducting Hemorrhage Control Training

	N	Gender		Education	Age	Prior Healthcare Trng		Prior Hemorrhage Trng		Prior Tourniquet Trng	
	Freq	Male	Female	*M*	*M*	Yes	No	Yes	No	Yes	No
Aggregate	27	17 (63.0)	10 (37.0)	15.2	21.6	21	6	10	17	9	18
Group A	12	3 (25.0)	9 (75.0)	15.4	23.3	12	0	3	9	2	10
Group B	15	14 (93.3)	1 (6.7)	15.0	20.1	9	6	7	8	7	8

Note, (%), *M*, indicates Mean.

Table 3

Overall Participant Time Difference		Time T_1	Time T_2
N	Valid	27	27
		Time 1	Time 2
Mean		47.89	54.86
Median		44.18	34.40
Std. Deviation		21.27	48.13
Range		90.97	181.05
Minimum		19.69	12.79
Maximum		110.660	193.84

Table 4

Prior Healthcare Training Time Difference in seconds

Prior Healthcare Training	Time Difference
No	13.5450
Yes	-7.3400
Total	-6.5700

Table 5

Reasons for Failure to Achieve Hemorrhage Control

	Time	MD Inches	Indent Yes	Indent No	Indent %	2 FT Yes	2 FT No	2 FT %	HC Yes	HC No	HC %
Aggregate	T1	5.6	26	1	96.3	27	0	100	26	1	96.3
	T2	5.3	24	3	88.9	24	3	88.9	24	3	88.9
Group A	T1	5.3	11	1	91.7	12	0	100	11	1	91.7
	T2	5.1	12	0	100	12	0	100	12	0	100
Group B	T1	5.9	15	0	100	15	0	100	15	0	100
	T2	5.4	12	3	80.0	12	3	80.0	12	3	80.0

Note, MD, indicates Mean Distance, 2 FT, indicates 2 Finger Test under the Tourniquet, HC, indicates Hemorrhage Control.

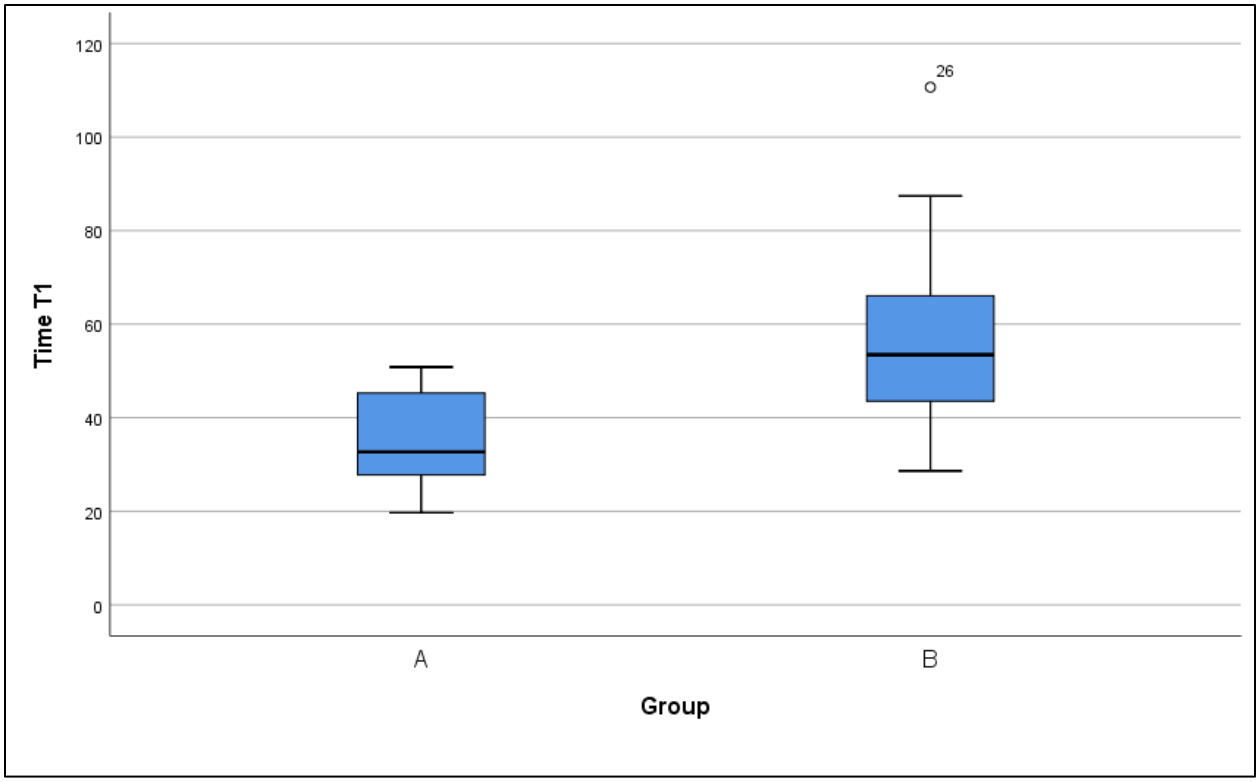

Figure 1. T_1 the tourniquet application times between Group A & B. Group A's T_1 median application time is less than Group B, with more uniform times, while Group B's T_1 median application time is slower with greater variance.

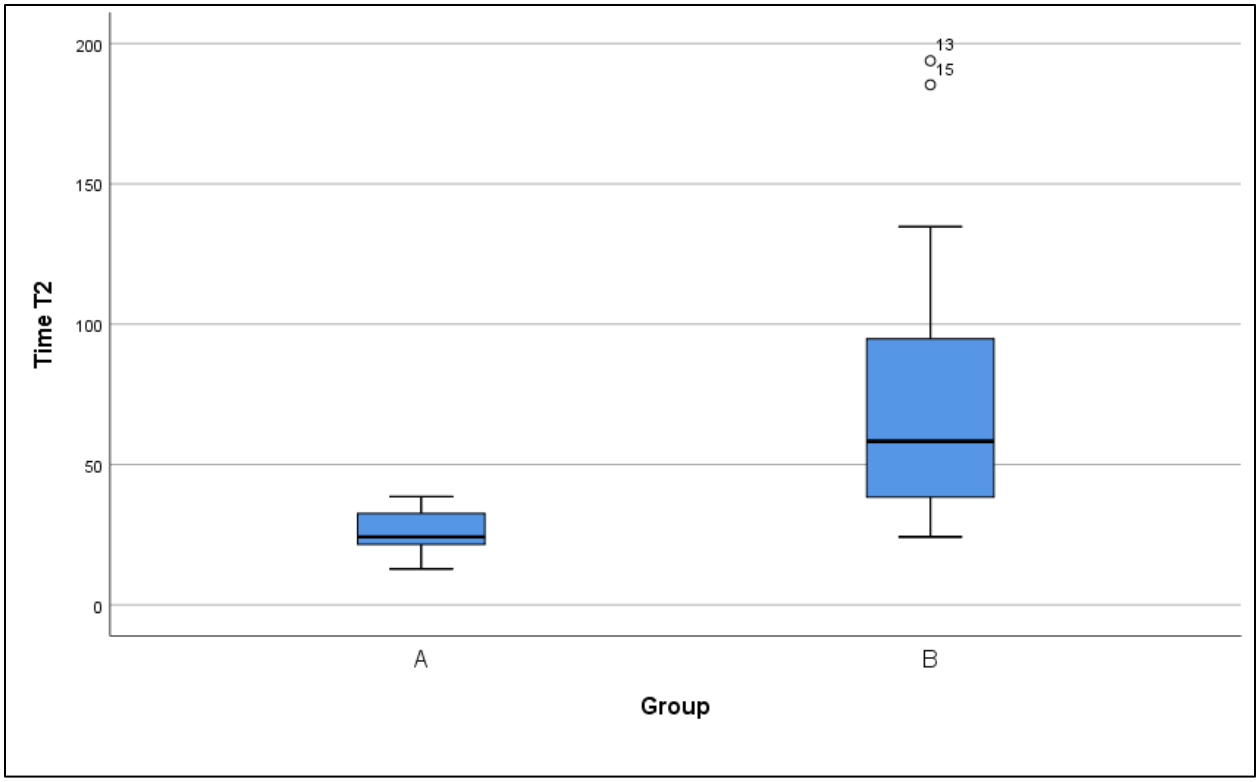

Figure 2. T_2 median tourniquet application times between Group A & B. Group A's times have decreased while simultaneously become more uniform. Group B's application times have increased, median has gotten slower, and greater outliers are present.