Injury, Int. J. Care Injured xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Can they stop the bleed? Evaluation of tourniquet application by individuals with varying levels of prior self-reported training☆

Justin C. McCarty[a], Edward J. Caterson[a,b], Muhammed A. Chaudhary[a], Juan P. Herrera-Escobar[a], Zain G. Hashmi[a], Scott A. Goldberg[c], Craig Goolsby[d], Stuart Lipsitz[a], Adil H. Haider[a], Eric Goralnick[a,c,*]

[a] Center for Surgery and Public Health (CSPH), Department of Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
[b] Division of Plastic Surgery, Department of Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
[c] Department of Emergency Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
[d] Department of Military & Emergency Medicine, Uniformed Services University of the Health Sciences, Bethesda, MD, USA

ARTICLE INFO

Article history:
Accepted 21 September 2018

Keywords:
Hemorrhage
Layperson
Preventable death
Bystanders
Tourniquet
Trauma

ABSTRACT

Background: Application of extremity tourniquets is a central tenet of multiple national initiatives to empower laypersons to provide hemorrhage control (HC). However, the efficacy of the general population who self-report prior first-aid (FA) or HC training on individual's ability to control bleeding with a tourniquet remains unknown. Therefore, the objective of this study was to assess the effectiveness of laypeople with self-reported prior FA or HC training to control bleeding with a tourniquet.
Study Design: Employees of a stadium were assessed via simulation in their ability to apply a Combat Application Tourniquet. As a subgroup analysis of a larger study, participants who self-reported: 1) No prior training, 2) FA training only or 2) FA + HC training were compared. Logistic regression adjusting for age, gender, education, willingness-to-assist, and comfort level in HC was performed.
Results: 317 participants were included. Compared to participants with no prior training (14.4%,n = 16/111), those with FA training only (25.2%,n = 35/139) had a 2.12-higher odds (95%CI:1.07-4.18) of correct tourniquet application while those with FA + HC (35.8%,n = 24/67) had a 3.50-higher odds (95%CI:1.59-7.72) of correct application. Participants with prior FA + HC were more willing-to-assist and comfortable performing HC than those without prior training ($p < 0.05$). However, reporting being very willing-to-assist [OR0.83,95%CI:0.43-1.60] or very comfortable [OR1.11,95%CI:0.55-2.25] was not associated with correct tourniquet application.
Conclusion: Self-reported prior FA + HC training, while associated with increased likelihood to correctly apply a tourniquet, results in only 1/3 of individuals correctly performing the skill. As work continues in empowering and training laypeople to act as immediate responders, these findings highlight the importance of effective layperson education techniques.

Introduction

In 2010, there were 173,140 deaths from trauma, making trauma a leading cause of death for individuals 1–45 years old in the United States [1]. One out of five civilian trauma deaths are deemed preventable, and within that cohort, uncontrolled hemorrhage accounts for up to 64% of preventable deaths [2,3]. In 2006, facing similarly high preventable death rates, the US military begazn focused training in hemorrhage control techniques, including recognition of life-threatening bleeding, manual compression, and tourniquet application [4]. This initiative resulted in a 63% decrease in deaths from uncontrolled hemorrhage with minimal morbidity attributed to tourniquet application [5–7]. This reduction in preventable deaths in the military was a key part of the Hartford consensus– a set of expert guidelines aimed at translating the military success in decreasing deaths from uncontrolled hemorrhage to the civilian sector [8]. Following these guidelines, several civilian initiatives, such as the "Stop the Bleed" Campaign, emphasize laypeople acting as immediate responders to stop bleeding through a combination of manual pressure, wound

Abbreviations: 95%CI, 95% confidence interval; OR, odds ratio; HC, hemorrhage control; FA, first-aid; B-Con, bleeding control for the injured basic course.

☆ Oral presentation at the 13th annual Academic Surgical Congress, Jacksonville, FL, February 2018.

* Corresponding author at: Brigham and Women's Hospital, Department of Emergency Medicine, 75 Francis Street, Boston, Mass, 02115, USA.
E-mail address: egoralnick@bwh.harvard.edu (E. Goralnick).

https://doi.org/10.1016/j.injury.2018.09.041
0020-1383/

packing, and early and rapid extremity tourniquet application [9,10]. To achieve this goal, training in hemorrhage control is being offered by multiple different venues throughout the US.

Numerous hemorrhage control courses are available to civilian laypeople in the US. Prominent examples include the American College of Surgeon's Committee on Trauma's Bleeding Control for the Injured Basic (B-Con) course, Tactical Emergency Casualty Care (TECC), the Federal Emergency Management Agency (FEMA) "You Are The Help Until Help Arrives" course, as well as many course variations offered by local medical and pre-hospital providers, many under the auspices of the "Stop the Bleed" campaign [11,12]. Many of these civilian courses use the Trauma Combat Casualty Care (TCCC) course, the course attended by many US soldiers since 2006, as a framework for their own implementation [4]. While TCCC has proven effective and serves as a reference for these civilian courses, there is a paucity of data to show similar efficacy for the civilian courses. The PATTS trial was the first study to show the skill decay that occurs following B-Con in the civilian population: 54.5% of laypeople retain the ability to control hemorrhage using a tourniquet 3–9 months after training. This data is reassuring, but a limitation remains that only a small portion of the overall US population has received this specific training. An additional aim of the Hartford Consensus and the "Stop the Bleed" campaign is to increase access to bleeding control kits containing commercial tourniquets to the public; however, varying types of prior training currently exist, and efficacy of the overall population who self-report training is unknown.

In this context, we performed a subset analysis of the Public Access and Tourniquet Training Study (PATTS) trial to assess whether different levels of self-reported prior training [no training, First-Aid training only (FA), and First-Aid plus Hemorrhage Control training (FA + HC)] are associated with correct tourniquet application among laypeople [13]. Our secondary objective was to assess participants self-reported willingness-to-assist and comfort level controlling hemorrhage and its relationship to tourniquet application. We hypothesize participants with prior self-reported FA + HC training will have a higher proportion of correct tourniquet application compared to participants with no prior training or FA only. Our secondary hypothesis is those individuals who self-report greater willingness-to-assist and greater comfort level in controlling hemorrhage will be more likely to apply a tourniquet correctly.

Methods

Study design

This is a subset analysis of the four-arm prospective randomized controlled PATTS trial. Partners Healthcare institutional review board approval was obtained for this study (protocol#: 2016P002631) and registered on clinicaltrials.gov (NCT03479112) [13]. As a subset analysis, the methods of study for participant assessment are the same as described in the main trial's manuscript. The predictor of interest in this subgroup analysis was prior training in first aid and hemorrhage control, as reported by the study subject. Training was divided into the following categories: no prior training, FA training only, and FA + HC training. The primary outcome was the proportion of participants who correctly apply a tourniquet. Secondary outcomes included self-reported willingness-to-assist in an emergency and self-reported comfort level in controlling hemorrhage for those with different levels of prior training.

Study participants

Participants were all employees of a major sports stadium in Boston, MA. The study was performed over a five-month period (April-August 2017). All participants were members of the stadium operational team (e.g. access control, parking staff, food and beverage workers, and stadium operations). For this subgroup analysis, we included all subjects in the PATTS trial who were in the control arm and those participants in the two intervention arms (audio-kit and flashcards) that did not utilize or interact with the available point-of-care instructions [13]. This subset analysis was not an *a priori* planned analysis during initial trial design and execution.

Study protocol

After giving consent, participants completed pre-training questionnaires detailing their demographic data and any prior FA training. If they reported previous FA training, they were asked whether it involved hemorrhage control training and to provide details of the hemorrhage control training via an open-ended question. Participants also reported their willingness-to-assist in an emergency and comfort level controlling hemorrhage on a 5-point Likert scale (1=very unwilling/uncomfortable, 5=very willing/comfortable).

Participants were read a scenario and then evaluated on their ability to apply a Combat Application Tourniquet (CAT) to a mannequin with an amputation of their leg representing an injured victim. A bleeding control kit containing a CAT tourniquet was provided to participants.

Correct tourniquet application was determined by sufficient distance above the injury, defined as at least 2 in. proximal to the amputation; adequate tightness of the tourniquet; and time to application of less than 7 min. [14] Tourniquet tightness was assessed by the observer attempting to forcefully slide a thin instrument between the tourniquet and mannequin. In the audio-guide and flashcard arm, participants interaction and/or utilization of the available point-of-care instructions was recorded by the observer.

Statistical analysis

The main outcome was the dichotomous outcome of correct tourniquet application. In bivariate analyses, the crude proportion of participants who correctly applied a tourniquet with no prior self-reported training, FA only, and FA + HC training were compared using three pairwise Pearson chi-square tests. Demographic variables were compared using Wilcoxon rank sum tests for continuous variables and chi-square tests for categorical variables.

To account for possible confounding, we performed multiple logistic regression to analyze the independent effect of self-reported FA and FA + HC, with no prior training as the reference group, on correct tourniquet application. Within the model, we included the categorical variables of age group (young adult 18–35 years old (yo), middle-aged adult 35–55 yo, and older adult >55 yo), education level (completed high school or less, some college education, bachelors or more advanced degree), and gender. The original trial arm was included in the model to adjust for potential confounding from exposure to an available point-of-care instructional prompt. We also included in the model self-reported willingness-to-assist in an emergency and self-reported comfort level to control hemorrhage to identify if these were independent predictors of correct tourniquet application. They were converted to a dichotomous outcome in the model with a report of very willing-to-assist (5 on Likert Scale) or very comfortable (5 on Likert Scale) as a positive report and any value less than that as the reference group (very unwilling/uncomfortable to somewhat willing/comfortable).

In a secondary analysis, the self-reported willingness-to-assist and comfort level controlling hemorrhage were treated as outcomes

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and compared across the three levels of training globally using one-way ANOVA and two-sample student t-tests via pairwise comparisons. Two-sample student's t-tests were used to compare responses within each of the three levels of prior training by whether or not an individual correctly applied a tourniquet.

A p-value of less than 0.05 was used to indicate statistical significance. Bonferroni correction for three pairwise comparisons was performed. Data were analyzed using Stata, v14.1 (Stata Corp., College Station, TX).

Results

Characteristics of participants

Of the 562 individuals who participated in the parent study, 317 met criteria for inclusion (Fig. 1). Among the 67 participants who reported prior HC training, the open-ended responses describing the type of HC training most often mentioned prior experience with tourniquets (n = 19, 28.3%), prior military training (n = 14, 20.9%) and/or prior EMT training (n = 8, 11.9%). The three levels of prior training were all comparable for age, gender, and maximum attained education level (Table 1). There was a higher proportion of men overall participating in the study (62.2%), but there were no differences in the proportion of men across the three levels of prior training.

Effect of prior training on tourniquet application

For our main study objective comparing correct tourniquet application in subjects with no prior training to subjects with only FA training, there was no difference between no prior training (n = 16/111, 14.4%) and FA training (n = 35/139, 25.2%) (p = 0.11). Those with FA + HC (n = 24/67, 35.8%) training had a higher proportion of correct application compared to those with no training (p = 0.003). There was no significant difference between FA training alone and FA + HC training (p = 0.34) (Fig. 2).

In the adjusted logistic regression model, with no prior training as the reference group, those with FA training had 2.12 higher odds (95%CI:1.07-4.18, p = 0.03) of correct tourniquet application and those with FA + HC training had 3.50-higher odds (95%CI:1.59-7.72, p = 0.002) (Table 2). Age group, prior education, and gender were not associated with correct tourniquet application.

Willingness-to-assist and comfort level controlling hemorrhage

Those with prior FA + HC training self-reported being more willing-to-assist than those with no prior training (p = 0.002) and FA training only (p = 0.04) (Table 3). There was no difference in willingness-to-assist between no prior training and FA training only (p = 0.87). Those with FA + HC self-reported being more comfortable controlling hemorrhage than those with less training (no prior training p < 0.001, FA training p = 0.04).

Stratified by level of training, there was no difference in willingness-to-assist or comfort level controlling hemorrhage between those individuals who applied a tourniquet correctly or incorrectly (Table 3). Within the adjusted model using lower reported self-efficacy values as the reference group (responses 1–4 on the 5-point Likert scale), participants who self-reported being very willing-to-assist [23.6%, n = 38, OR 0.83, 95%CI(0.43–1.60)] or very comfortable controlling hemorrhage [n = 25, 27.5%, OR 1.11, 95%CI(0.55–2.25)) were no more likely to correctly apply a tourniquet than those reporting being less willing-to-assist or comfortable controlling hemorrhage (Table 2).

Discussion

This study demonstrates that individuals who self-report prior First-Aid and First-Aid + Hemorrhage Control training are more successful at correctly applying a combat application tourniquet than individuals without prior training. However, the proportion of correct tourniquet applications still remains low, with only approximately one-third of subjects with prior FA + HC correctly applying a tourniquet. Further, independent of prior training, we found participants who self-report being very willing-to-assist in an emergency and very comfortable controlling hemorrhage were no more likely to correctly apply a tourniquet than participants who were less willing or less comfortable controlling hemorrhage.

As we work towards building a resilient population of individuals who are willing and capable of acting as immediate responders, this study provides insight into the potential efficacy of the general population to correctly administer time sensitive hemorrhage control in the form of tourniquet application. Our finding that those with self-reported prior FA + HC training are able to correctly apply a tourniquet more often than those without reported training is reassuring in that training is correlated with success. However, the rate of correct tourniquet application is still concerningly low, at only 35.8% for those with FA + HC training. This rate is similar to that seen in CPR skill retention which has been shown to drop to approximately 30% 2-months after completing training [15]. The second portion of the PATTS trial, which assessed retention of hemorrhage control training 3–9 months after undergoing Bleeding Control Basic (B-Con) training, demonstrated that 54.5% of individuals are able to control hemorrhage with a tourniquet following training without further skill decay over the

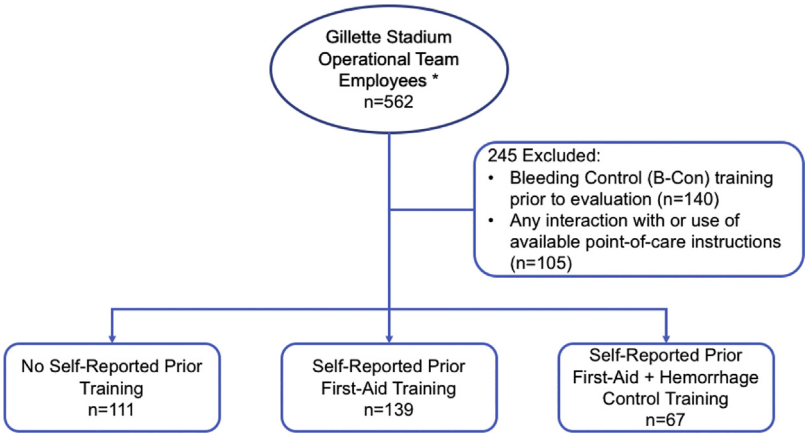

Fig. 1. Inclusion and Exclusion Criteria.

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Table 1
Demographic Data.

		Overall (n = 317)	No Prior training (n = 111)	First aid training only (n = 139)	First aid and Hemorrhage control training (n = 67)	p-value
Age (mean(SD)]		47.7 (15.9)	46.9 (18.5)	48.6 (14.1)	46.9 (14.6)	0.66
Gender[a]	male	197 (62.2%)	68 (61.3%)	81 (58.3%)	48 (71.6%)	0.51
	female	118 (37.2%)	42 (37.8%)	58 (41.7%)	18 (26.9%)	
Education level	High School or less	60 (18.9%)	28 (25.2%)	25 (17.9%)	7 (10.5%)	0.16
	Some College education	141 (44.5%)	43 (38.7%)	65 (46.8%)	33 (49.3%)	
	Bachelors or other more Advanced Degree	115 (36.4%)	39 (35.5%)	49 (35.3%)	27 (40.3%)	

[a] 2 participants did not answer the question on gender and 1 participant did not answer the question on highest attained education level.

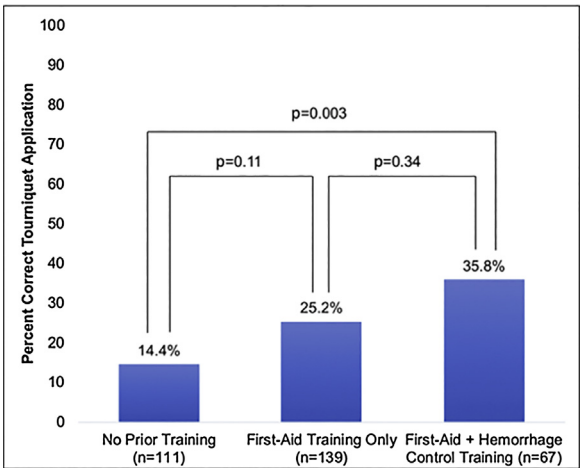

Fig. 2. Unadjusted Analysis of the Effect of Different amounts of Self-Reported Prior Training on Correct Tourniquet Application.
Fig. 2 Legend: Participants with self-reported prior First-Aid + Hemorrhage Control training are more likely than those with no training to correctly apply a tourniquet. There is no difference between no prior training and First-Aid training alone and no prior training and First-Aid + Hemorrhage Control training.

3–9 month time period. These proportions, 35.8% and 54.5%, while showing differing levels of skill retention over time, show the need to address what the best method to enable the public to control hemorrhage should be; whether that be classroom and hands-on training as was done in the PATTS trial, web-based education, or improved point-of-care instructions accompanying bleeding control kits. Goolsby et al. has shown in 3 separate studies that well designed and implemented point-of-care instructions can result in rates of correct tourniquet application between 44–75%, though the subsequent PATTS trial demonstrated lower rates of success with current point-of-care prompts [13,14,16,17].

There are currently no studies describing the correct application or incidence of civilians placing tourniquets in the pre-hospital setting [18]. This lack of knowledge about whether laypeople know how to control bleeding is a key missing data point for national preparedness campaigns for hemorrhage control. Multiple studies have shown that placement of a tourniquet by emergency medical personnel, similar to the military experience, decreases the risk of death only if placed before the onset of hemorrhagic shock, a role laypersons can fill by already being on the scene [5,18–20]. The proportion of correct application of 14.4% for those with no training, up to 35.8% with FA + HC training, may act as a proxy for what to expect the rate of correct tourniquet application would be if bleeding control kits were readily available to civilians. These numbers can inform current and future implementation projects relating to civilian hemorrhage control preparedness. Bulger et al. recently suggested that it is not necessary to reach 100% saturation for hemorrhage control readiness among the general population, but rather to attain a critical threshold in order to reach a "herd immunity" such that at least one individual would have the necessary skills to stop bleeding [21].

Events such as the Boston Marathon bombing, wherein 27 extremity tourniquets were applied by a combination of laypeople and professional first-responders, have shown the willingness of laypeople to act [22]. There remain questions about the effectiveness of the applied tourniquets as all 27 tourniquets were improvised, which are known to be difficult to correctly apply without proper training or supplies, but the willingness of bystanders to act was clear [23,24]. Studies in the prehospital setting have similarly shown laypeople are willing to provide aid before the arrival of first-responders in multiple different situations, and prior training is associated with increased odds of layperson intervention [25–27]. This corresponds with the responses of individuals in our study which showed higher median self-reported willingness-to-act and comfort level in hemorrhage control for those with prior reported FA + HC training compared to no training. However, it is important to note that within each training level and overall, both willingness-to-assist and comfort level do not correlate with correct tourniquet application which raises concern for potential misplaced confidence of participants. But, similar to other first-aid skills, evidence suggests any civilian action is superior to inaction in the pre-hospital setting, including in trauma [28,29].

There are limitations to this study. As a post-hoc analyssis of a larger randomized trial, it was not designed to specifically assess our current research question. There is potential for confounding from exposure to the different treatment arms. Within the adjusted model, we address this limitation by including the intervention arm to reduce this potential bias. The other significant limitation of describing the effect of prior hemorrhage control training is that there is incomplete information regarding when and the type of training participants received in the past. The open-ended questions included responses including prior military training (n = 14, 20.9%), training as an EMT (n = 8, 11.9%), and prior experience with tourniquets (n = 19, 28.3%). This limits the comparison to the PATTS trial retention testing where all participants exact training and retention testing dates were known. Similar to the limitation in the PATTS trial, this study only evaluated a single component of hemorrhage control and only evaluated one type of commercial tourniquet. While tourniquets are a critical element of hemorrhage control, further research is needed on laypersons' ability to recognize life threatening bleeding, call for help and choose the best intervention to include compression, packing and/or a tourniquet [18].

Future research should evaluate the effect national bleeding control initiatives like "Stop the Bleed" have had on mortality relating to uncontrolled hemorrhage. To aid this effort, registries

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Table 2
Multiple Logistic Regression for Demographic Predictors of Correct Tourniquet Application.

	Unadjusted Proportion of Correct Tourniquet Application	Odds Ratio (95% CI)	p -value
Prior Training			
No Prior Training (n = 111)	16 (14.4%)	*ref*	
First-Aid Training only (n = 139)	35 (25.2%)	**2.12 (1.07–4.18)**	**0.03**
First aid + Hemorrhage Control training (n = 67)	24 (35.8%)	**3.50 (1.59–7.72)**	**0.002**
Education Level			
High School or Less (n = 60)	12 (20.0%)	*ref*	
Some College education (n = 141)	29 (20.6%)	0.80 (0.36–1.78)	0.59
Bachelors or Advanced Degree (n = 115)	34 (29.6%)	1.39 (0.63–3.09)	0.41
Age Group			
Young adult (18–35 yo) (n = 82)	17 (20.7%)	*ref*	
Middle-Aged Adult (35–55 yo) (n = 115)	25 (21.7%)	0.99 (0.48–2.07)	0.99
Older Adult (> 55 yo) (n = 110)	32 (29.1%)	1.50 (0.74–3.04)	0.26
Gender			
Women (n = 118)	22 (18.6%)	*ref*	
Men (n = 197)	52 (26.4%)	1.37 (0.74, 2.52)	0.31
Original Trial Arm			
Control (n = 138)	28 (20.3%)	*ref*	
Audio-kit (n = 98)	27 (27.6%)	1.49 (0.78, 2.85)	0.23
Flashcards (n = 81)	20 (24.7%)	1.18 (0.59, 2.40)	0.64
Self-Reported Willingness-to-Assist (Reference: value 1–4)[a]			
Very Willing-to-Assist (n = 161)	38 (23.6%)	0.83 (0.43, 1.60)	0.58
Self-Reported Comfort Level Controlling Hemorrhage (Reference: value 1–4)[a]			
Very Comfortable (n = 91)	25 (27.5%)	1.11 (0.55–2.25)	0.77

First-aid training and first-aid + hemorrhage control training are both significantly correlated with correct tourniquet application compared to no prior training in the adjusted model.

[a] Data obtained on 5-point Likert scale with 1 = very unwilling-to-assist/uncomfortable controlling hemorrhage and 5 = very willing-to-assist/comfortable controlling hemorrhage.

Table 3
Comparison of Self-Efficacy for Different Levels of Prior Training and Relationship to Correct Tourniquet application.

	Overall, mean(SD)		Correct Tourniquet Application, mean(SD)	Incorrect Tourniquet Application, mean(SD)	p-value
	Mean Willingness-to-Assist[a]				
No Prior Training (n = 111)	3.91 (1.17)	p=0.004	3.88 (1.36)	3.91 (1.14)	p = 0.89
First-Aid Training only (n = 139)	4.07 (1.24)		3.86 (1.33)	4.14 (1.20)	p = 0.24
First-Aid and Hemorrhage Control Training (n = 67)	4.51 (0.98)		4.50 (1.02)	4.51 (0.96)	p = 0.96
	Mean Comfort Level in Hemorrhage Control[a]				
No Prior Training (n = 111)	3.35 (1.09)	p < 0.001	3.19 (1.22)	3.38 (1.07)	p = 0.47
First-Aid Training only (n = 139)	3.67 (1.19)		3.63 (1.17)	3.68 (1.20)	p = 0.82
First-Aid and Hemorrhage Control Training (n = 67)	4.10 (1.09)		4.25 (1.03)	4.02 (1.12)	p = 0.42

There was a significant difference across the different levels of training for the mean willingness-to-assist and comfort level ($p < 0.05$). Those with FA + HC had higher mean responses for both questions than those with less training ($p < 0.05$ for each). No difference was present in either willingness-to-assist or comfort level controlling hemorrhage within each level of training whether participant correctly or incorrectly applied a tourniquet.

[a] Data obtained on 5-point Likert scale with 1 = very unwilling-to-assist/uncomfortable controlling hemorrhage and 5 = very willing-to-assist/comfortable controlling hemorrhage.

such as the National Emergency Medical Services Information System (NEMSIS) which currently collects data about EMS application of tourniquets, could identify whether tourniquets were applied by civilians at the scene before EMS arrival [30].

Conclusion

Prior reported hemorrhage control training is correlated with increased odds of correct tourniquet application by laypeople and increases subjects reported willingness-to-assist in emergencies. However, the rate of correct tourniquet application remains low at just over one third. These findings should help to inform the national conversation surrounding layperson hemorrhage control as work continues to reach the goal of zero preventable deaths from injury [3].

Disclosures

Disclaimer: The views expressed in this publication are those of the authors and do not reflect the official policy or position of the Uniformed Services University, Department of Defense, or the United States Government. Justin C. McCarty receives fellowship funding from the Stepping Strong Center for Plastic Surgery Trauma Innovation.

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Conflict of interest

No authors have any conflicts of interest to disclose relating to this work.

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Please cite this article in press as: J.C. McCarty, et al., Can they stop the bleed? Evaluation of tourniquet application by individuals with varying levels of prior self-reported training, Injury (2018), https://doi.org/10.1016/j.injury.2018.09.041