Effect of Uniform Design on the Speed of Combat Tourniquet Application: A Simulation Study

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ABSTRACT Background: Tourniquets are issued to deployed members of both the United States (U.S. military and the Australian Defence Force (ADF). The ease of removing the tourniquet from the pocket of the combat uniform may influence its time to application. The ADF uniform uses buttons to secure the pocket, whereas the U.S. uniform uses a hook and loop fastener system. National differences in training may influence the time to and effectiveness of tourniquet application. Objectives: To compare the time taken to retrieve and apply a tourniquet from the pocket of the Australian and the U.S. combat uniform and compare the effectiveness of tourniquet application. Methods: Twenty participants from both nations were randomly selected. Participants were timed on their ability to remove a tourniquet from their pockets and then apply it effectively. Results: The U.S. personnel removed their tourniquets in shorter time (median 2.5 seconds) than Australians (median 5.72 seconds, $p < 0.0001$). ADF members (mean 41.36 seconds vs. 58.87 seconds, $p < 0.037$) applied the tourniquet more rapidly once removed from the pocket and trended to apply it more effectively ($p = 0.1$). Conclusions: The closure system of pockets on the combat uniform might influence the time taken to apply a tourniquet. Regular training might also reduce the time taken to apply a tourniquet effectively.

INTRODUCTION

Uncontrolled hemorrhage remains the leading cause of death in potentially survivable combat casualties.[1] Body armor has decreased life-threatening thoracoabdominal hemorrhage, but has done little to reduce the trauma to the appendicular skeleton.[2] As in ancient times, the tourniquet continues to be the primary device for the control of life-threatening extremity hemorrhage and has become commonplace on the modern battlefield. For accessibility and prompt application, most coalition combat units encourage their service members to store the device in the top right arm pocket of the combat uniform. The United States (U.S.) military and Australian Defence Force (ADF) utilize the Combat Application Tourniquet (C-A-T, Composite Resources, Rock Hill, South Carolina). The ADF Disruptive Pattern Camouflage Uniform (DPCU) has buttons to secure the arm pocket flap closed (Fig. 1), whereas the U.S. Multicam (Crye Precision, Brooklyn, New York) version employs a hook and loop fastener system (Velcro) (Fig. 2). We hypothesized that the method of storage of the C-A-T within the uniform may affect the timing of its application. We further hypothesized that differences in training would also affect time to application and efficacy of application (defined as obliterating the radial pulse). The purpose of this investigation was to test whether the uniform pocket closure design from two different services (U.S. military and ADF) had an effect on the overall time to tourniquet application.

METHODS

After formal written exemption from the requirement to gain institutional review board or ethics committee approval from both the U.S. Central Command and the Australian Defence Human Research Ethics Committee, we selected a sample of volunteers comprising 20 members of the U.S. armed forces and 20 members of the ADF at Kandahar Airfield, Afghanistan. After a brief, scripted explanation, we instruct them to apply a C-A-T to the right upper arm. All participants were instructed to apply the tourniquet to the right arm using a one-handed technique with the left hand only. The tourniquet used was supplied, folded, and positioned in a standard fashion by the investigator into the participant's pocket and the buttons or hook and loop fastener system secured closed. The participants were then instructed to apply their tourniquet as quickly as they could.

We recorded time to remove the tourniquet from the pocket, total time to apply the tourniquet, and the absence or presence of a radial pulse after application. We defined successful removal from the pocket to be when the tourniquet was held in the hand outside the pocket (as visually confirmed by the investigator) but not necessarily unfolded and ready to apply. Absence of a palpable radial pulse indicated effective application of the tourniquet. We then questioned participants regarding specific epidemiological data including gender, nationality, branch of service, trade, age, time since training on the tourniquet and handedness.

The primary outcome was time to removal of the tourniquet from the pocket, as this is the best measure of the effect of the pocket closure system. Data were assessed for normality, and groups were compared using either unpaired student's *t*-tests or Mann–Whitney *U* tests, as appropriate. Multivariable regression analyses (linear and logistic, as appropriate for continuous and categorical variables) were also performed to determine whether any of the other putative predictor variables listed above significantly confounded the relationship between the hypothesised main predictor (pocket closure

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FIGURE 1. ADF pocket.

FIGURE 2. U.S. military pocket.

type) and outcome. Modelling was performed using backwards stepwise regression beginning with all listed variables, with $p < 0.2$ used for retention in the model.

A pilot study involving 20 U.S. and 20 Australian service members was performed to assess the sample size required to identify (with >80% power) a statistically significant ($p < 0.05$) difference between the groups if one existed. Further subjects were planned to be enrolled if required, with adjustment for one interim analysis (if this was required) in the final statistical tests.

RESULTS

The two groups were comparable with respect to age, gender, handedness, time since training, and branch of service. There was significantly more medical staff (20%) in the ADF group than the U.S. group as shown in Table I.

ADF members were significantly slower to remove the tourniquet from the pocket, requiring a median time of 5.72 seconds (interquartile range [IQR] 4.42–9.46) vs. 2.5 seconds for U.S. personnel (IQR 2.15–3.165) ($p < 0.0001$). The mean time from removal of the tourniquet from the pocket to application of the tourniquet was less for ADF members (41.36 seconds) vs. U.S. personnel (58.87 seconds) ($p = 0.037$). There was no difference in overall time to apply the tourniquet indicating that the Australians had compensated for the initial delay in removing the tourniquet from the pocket. There was a strong trend ($p = 0.1$) toward a difference in the rate at which the pulse was obliterated, suggesting Australians (73.7% obliterated the radial pulse) applied the tourniquet more effectively than the U.S. service members (42.1%).

TABLE I. Characteristics of the Study Cohort

Characteristics	Australian	United States	*p* Value
Gender, % Male	75	85	0.695
Handedness, % Right-Handed	88.2	84.2	1
Branch of Service (%)			0.096
Army	50	75	
Air Force	50	20	
Navy	0	5	
Occupation (%)			0.038
Combat Support	75	75	
Medical	20	0	
Combat	5	25	
Age, Years, Median (IQR)	34.5 (27.5–42.5)	28.5 (24.0–39.5)	0.218
Time Since Training, Days, Median (IQR)	100 (42–150)	120 (60–280)	0.184

In the multivariable analysis, U.S. nationality remained a significant predictor of quicker time to removal of the tourniquet from the pocket (coefficient = −5.15, $p < 0.0001$). Left-handedness was a significant predictor of longer time to removal (coefficient = 3.92, $p = 0.012$). U.S. nationality remained associated with a significantly longer time after removal of the tourniquet from the pocket to application (coefficient = 21.57, $p = 0.017$). Briefer time since training showed a weak trend to shorter time to application (coefficient = −0.07, $p = 0.129$). U.S. nationality was associated with a significantly lower chance of obliterating the pulse (coefficient = −18.88, $p < 0.0001$), as was being in the Air Force (coefficient = −19.10, $p < 0.0001$) and being left-handed (coefficient = −18.70, $p < 0.0001$).

DISCUSSION

U.S. personnel, utilizing the Velcro system, removed the tourniquet 3.22 seconds faster than ADF members from the pocket, whose DPCU employs a button closure system. This may seem inconsequential until one considers the additional blood loss, as a result of this delay. The additional blood lost is difficult to quantify though can be approximated. Flow through the femoral artery during submaximal exercise has been estimated using Doppler studies to be 7.22 L/min.[3] Based on these flow studies, a 3.22 second delay in accessing the C-A-T could result in substantial additional blood loss, potentially escalating the casualty into a higher grade of shock. The deterioration in mental status, initiated as the degree of shock worsens, may further affect the successful application of the tourniquet. The situation is exaggerated if outliers from the data are considered. The most extreme time to removal in the ADF group was 21.6 seconds, whereas in the U.S. group this was 5.5 seconds (difference 16.1 seconds).

Training should influence the chance of successful application. This study suggests that the ADF's training may be superior to that of the U.S. personnel studied, and that this training was sufficient to compensate for a less efficient design of the shoulder pocket button closure system. The ADF members were more likely to obliterate the radial pulse and once the tourniquet was removed from the pocket, apply it in a shorter period of time. Although no participant reported not to have received training with the C-A-T, ADF members as part of a mandatory predeployment package receive at least two periods of instruction in the Care of the Battle Casualty Course regardless of trade or rank. This course is delivered both before deployment and again after arrival in the area of operations. U.S. forces with the exception of combat medical personnel do not receive such mandatory predeployment training with the C-A-T. All U.S. nonmedical personnel, however, are instructed during basic training and annual refresher combat skills training, though not necessarily as part of a predeployment package as is the case with ADF personnel.

Although not reaching significance in this study participants with shorter periods since last training with the C-A-T showed a strong trend to a shorter time to application. Just as currency of weapons training is thought to affect performance and so is mandated, this study suggests the regular reinforcement training with the C-A-T should be performed.

Despite our efforts to control for confounding using multivariable adjustment for imbalances in group characteristics, the possibility of residual confounding limits the generalizability of our findings. Furthermore, the effect of familiarity or training with the different types of uniform (as opposed to the alternate explanation of truly better uniform design) could have been investigated using a crossover design in which the U.S. and ADF personnel performed the same activity wearing both uniform types. Other limitations to this study include its small sample size and lack of randomization.

CONCLUSION

Although the generalizability of this study is limited by its small sample size, our results suggest that the pocket closure system incorporated into the combat uniform might influence the time to application of a tourniquet. Simple changes made to the U.S. combat uniform have made access to the tourniquet quicker in comparison to the ADF DPCU. We are unable to comment on whether other effects of choosing hook-and-loop fastening over buttons (such as durability and noise) should influence uniform design decisions. Our results further suggest that training can mitigate the effect of uniform design on time to effective tourniquet application. Training with the use of the tourniquet should be regularly reinforced and mandatory for deploying personnel. A larger study with a crossover design may reduce potential confounding seen in this pilot study.

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