Assessment of User, Glove, and Device Effects on Performance of Tourniquet Use in Simulated First Aid

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ABSTRACT

Background: The effects of users, glove types, and tourniquet devices on the performance of limb tourniquet use in simulated first aid were measured. **Materials and Methods:** Four users conducted 180 tests of tourniquet performance in eight glove groups compared with bare hands as a control. **Results:** Among tests, 99% (n = 179) had favorable results for each of the following: effectiveness (i.e., bleeding control), distal pulse stoppage, and tourniquet placement at the correct site. However, only 90% of tests ended with a satisfactory result, which is a composite outcome of aggregated metrics if all (patient status is stable, tourniquet placement is good, and pressure is good) are satisfactory. Of 18 unsatisfactory results, 17 (94%) were due to pressure problems. Most of the variance of the majority of continuous metrics (time to determination of bleeding control, trial time, overall time, pressure, and blood loss) could be attributed to the users (62%, 55%, 61%, 8%, and 68%, respectively). Glove effects impaired and slowed performance; three groups (cold gloves layered under mittens, mittens, and cold gloves) consistently had significant effects and five groups (examination gloves, flight gloves, leather gloves, glove liners, and glove liners layered under leather gloves) did not. For time to bleeding control and blood loss, performance using these same three glove groups had worse results compared with bare hands by 26, 18, and 17 seconds and by 188, 116, and 124mL, respectively. Device effects occurred only with continuous metrics and were often dominated by user effects. **Conclusion:** In simulated first aid with tourniquets used to control bleeding, users had major effects on most performance metrics. Glove effects were significant for three of eight glove types. Tourniquet device effects occurred only with continuous metrics and were often dominated by user effects.

Keywords: *glove; mitten; manual skill; psychomotor performance; tourniquet; first aid; hemorrhage, prevention and control*

Introduction

In first aid training, learners are routinely taught to consider precautions when rendering care, such as by donning clean gloves to protect their hands from the blood of patients or from injury on sharp spicules of bone.[1–4] A US public safety effort called "Stop The Bleed" advises people to "Protect yourself from blood-borne infections by wearing gloves, if available."[5] Standard precautions are an approach to control infection by considering all human blood and certain other body fluids to carry infectious pathogens like viruses, which can cause diseases such as hepatitis.[6,7] Besides hand hygiene, the use of personal protective equipment like gloves should be guided by the assessment of situational risks, including the anticipated extent of personal contact with fluids.[7–10]

Beyond caregiving, military Servicepersons use an array of glove types, such as cold-weather gloves with over-mittens in arctic environments or tactical gloves for shooting. In a previous study, we unwrapped tourniquets from their packages while wearing gloves and compared this performance with doing the same with bare hands;[11] the current study followed that one to check performance in simulated caregiving.

Although nonsterile gloves are the most common type of personal protective equipment used in caregiving, there is little science to help us understand how performance of manual caregiving skills differs by the type of gloves worn.[12–20] We looked at how results were affected by users, gloves, and tourniquets, with all three individually identified in this study. For example, when a tourniquet had wear and tear after use, it was replaced by another device of the same model. Statistically, we could then compare effects of individual users, glove types, and devices. The purpose of this study was to measure the effects of users, glove types, and tourniquet devices on performance of limb tourniquet use in simulated first aid.

Materials and Methods

The study was a controlled experiment conducted following protocol guidelines at the US Army Institute of Surgical Research from April to July 2016. The study followed our earlier study[11] involving the same persons, materials, and protocol.

There were nine glove groups. Bare hands were the control group. The eight experimental groups were (1) examination gloves, (2) flight gloves, (3) glove liners, (4) leather gloves, (5) glove liners layered under leather gloves, (6) cold gloves, (7) mittens, and (8) cold gloves layered under mittens. Four

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persons participated one at a time to apply tourniquets: a clinician-scientist, an associate researcher, a military cadet, and a research scientist, numbered users 1 through 4, respectively.

The limb tourniquet model was the generation 6 Combat Application Tourniquet (C-A-T; C•A•T Resources, www.combattourniquet.com). Tourniquets were already unwrapped and reconfigured for one-handed use. The user donned the gloves by glove group in a randomized order. After starting, the user unrouted the tourniquet band by removing it from its course through a slit in the buckle, and then the user applied the tourniquet to the manikin. If wear or tear of a tourniquet device occurred, it was replaced upon completion of the test. Each user started with an unused tourniquet. Two devices sustained wear or tear and were replaced, making a total of six devices used in the study.

Because the intervention required the glove group, the tourniquet, and the user altogether, there was no capacity to statistically differentiate between them for an individual test.[20] However, looking at all tests allowed analysis of effects of users, gloves, and devices. The number of tests was 180. The four users performed five tests of the nine glove groups each, for a total of 45 tests each.

The manikin on which we tested the performance of tourniquet use was reported previously.[22] Briefly, a HapMed™ Leg Tourniquet Trainer (CHI Systems, http://www.chisystems.com) simulated a right thigh with an amputation injury. Run-time feedback was off. Metrics included effectiveness in bleeding control as a yes or no result, time in seconds to determination of bleeding control, trial time (sum of time to determination of bleeding control and time to remove the tourniquet from its wrapper), distal pulse stoppage (yes or no), patient status (stable, bleeding, or dead), tourniquet placement (none [no tourniquet detected], good [location], or incorrect [location]), tourniquet pressure (amplitude in mmHg and categorized as loose, good, or tight), blood loss in milliliters, and test status. Test status was a composite binary result (i.e., satisfactory or unsatisfactory result) indicating whether the test was, in aggregate, satisfactory for all the following metrics: patient status was stable, tourniquet placement was good, and pressure was good. The manikin reported satisfactory test status as a 'go'. Pulse stoppage was determined by the user; the manikin determined the rest.

All data were generated during the present study except for time to unwrap, which came from the prior study.[11] Unwrapping times were specific to the user, glove group, and model of C-A-T tourniquet, but there was only one set of nine times for each user because there were nine glove groups. To simulate a realistic time it takes to use a tourniquet, an additional metric was generated by summing the time to unwrap and the trial time; this was used as an overall time. No bleeding occurred while unwrapping.

Descriptive statistics were used to portray results. Categorical data were analyzed by contingency tables, and likelihood ratios were calculated. Continuous data (e.g., time to determination of bleeding control) were summarized by median (range) or mean (standard deviation), which were analyzed using analysis of variance (ANOVA) to see differences. Fixed-effect tests were made by glove group and by tourniquet device. For pairwise comparisons of group means, a nonparametric Wilcoxon method or Tukey least significant difference (LSD) method was used, whichever was most appropriate. The number of pairwise comparisons for the nine glove groups was 36 ([{9 – 1} × 9]/2); the number of pairwise comparisons for the four individual users and six individual tourniquet devices was six and 15, respectively. LSD and Dunnett corrections were used for pairwise comparisons. Pairwise comparisons of group means were then put into levels based on statistical significance.

A mixed-model ANOVA was also used, which included the user as a random effect in the model. User effects were presented as a percentage of the overall variance component based on the restricted maximal likelihood variance method. R^2 was reported as the percentage of the response variable variation that is explained by a linear model. Significance for results was established when $p < .05$. All statistical analyses were conducted with SAS software (JMP version 12.0; SAS Institute, http://www.sas.com) and MS Excel 2003 (Microsoft; www.microsoft.com).

Results

Effectiveness in Bleeding Control

For users, 179 of the 180 tests (99%) ended with effectiveness, and interuser differences were not statistically significant (p = .4252). User 2 had the ineffective test.

For gloves, 99% of the tests resulted with effectiveness, and intergroup differences were not significant (p = .8154). The ineffective test was with cold gloves layered under mittens.

For devices, six individual tourniquets were used. Users 1 and 3 had one each; users 2 and 4 had two each. Of 180 tests, 179 resulted in effectiveness, and the ineffective test was with device U2-2 (user 2's second device). Interdevice differences were not significant (p = .2965).

Pulse Stoppage

For users, gloves, and devices, 99% of tests resulted in pulse stoppage, and interuser, interglove, and interdevice differences were not significant (p = .4252, .8154, and .2965, respectively). User 2 had the test without stoppage, which was performed with cold gloves layered under mittens and device U2-2.

Patient Status

For users, 99% of tests resulted with the patient as stable, and interuser differences were not significant (p = .4252). User 2's final test ended with bleeding.

For gloves, results were similar: 99% of tests ended with the patient stable; one test, in which cold gloves were layered under mittens, ended with bleeding (p = .8154).

For devices, 99% of tests resulted with the patient as stable. The test with bleeding was with device U2-2. Interdevice differences were not significant (p = .2965).

Tourniquet Placement: Incorrect Placement or Good Placement at the Correct Site

For users, gloves, and devices, 99% of tests resulted with good tourniquet placement, and interuser, interglove, and interdevice differences were not significant (p = .4252, .8154, and

.5518, respectively). User 4 put the tourniquet atop the wound and not 2–3 inches above; this test was with device U4-2 (user 4's second device) and the user was wearing leather gloves.

Trial Status

For users, gloves, and devices, 90% of the tests (162 of 180) ended with a satisfactory result. Interuser, interglove, and interdevice differences were not significant (p = .8732, .1727, and .6776, respectively).

Time to Determination of Bleeding Control

The mean time to determination of bleeding control was 34 ± 17.4 seconds (median, 31 seconds; minimum, 11 seconds; maximum, 111 seconds; range, 100 seconds). The 10-fold range in times indicated that performance varied broadly, with long times causing the wide breadth in times.

For users, results could be separated into three levels. User 1, the most experienced, was alone in the fast level; user 4, the least experienced, was alone in the slow level; users 2 and 3, at 33 and 34 seconds, respectively, were of intermediate experience with midlevel results. The analysis showed that 62% of the variance of times to determination of bleeding control could be attributed to the users. Users showed no or mild learning when time in regression was checked by use number (R^2 < .2662 for all four users).

For gloves, time to bleeding control was fastest with bare hands and examination gloves (the two glove groups which were thinnest), and slowest with cold gloves layered under mittens—the thickest-glove group. Each level followed the pattern, which was generally scalable, of time to bleeding control being slower with the thicker-glove group. Among 36 pairwise comparisons of difference between group means, 13 were significant (p < .0428, all 13 pairs; Table 1). In regression of comparisons, the difference in glove-thickness by group was moderately associated with the difference in mean time (time difference = 4.3613 × thickness difference + 4.9812; R^2 = 0.3475). By the Dunnett method, three glove-group means (cold gloves layered under mittens, mittens, and cold gloves) were significant (p < .0103, all three; Table 2). Times were slowed by wearing gloves as compared with bare hands. Glove effects on bleeding control for these three groups were longer than for bare hands by 26 seconds, 18 seconds, and 17 seconds, respectively.

For devices, results came in three levels. Devices U4-1 and U4-2 constituted the slow level, whereas U1-1 was alone in the fast level. Devices U2-1, U2-2, and U3-1 were in the midlevel. Device effects when parsed for intrauser results, therefore, were consistently in the same level. Among 15 pairwise comparisons of difference between device means, 11 were significant (p < .0306, all 11 pairs).

Trial Time

The mean trial time was 50 ± 19.0 seconds (median, 45.5 seconds; minimum, 21 seconds; maximum, 123 seconds; range, 102 seconds). Thus, there was a sixfold range in trial times.

For users, results had the same pattern as time to determination of bleeding control. The analysis showed that 55% of the variance of results in trial time could be attributed to the users.

For gloves, results came in five levels. Bare hands and examination gloves were in the fastest level along with glove liners and flight gloves, whereas cold gloves layered under mittens were alone in the slowest level, repeating the pattern seen in longer time to hemorrhage control with thicker gloves. By the Dunnett method, five glove-group means (cold gloves layered under mittens; mittens; cold gloves; leather gloves; and leather gloves and glove liners) were significantly slower than the mean for bare hands (p < .0295, all five). The gloves in these five glove groups were the thickest.

Table 1 *Pairwise Comparison[a] of Group Means in Time to Determination of Bleeding Control[b]*

Glove Groups Compared	Mean Difference (seconds)	p Value
Cold gloves and mittens: bare hands	25.85	<.0001
Cold gloves and mittens: examination gloves	19.80	.0002
Cold gloves and mittens: glove liners	18.40	.0004
Mittens: bare hands	17.90	.0006
Cold gloves and mittens: flight gloves	16.95	.0011
Cold gloves: bare hands	16.55	.0015
Leather gloves: bare hands	13.70	.0082
Cold gloves and mittens: glove liners and leather gloves	13.50	.0092
Glove liners and leather gloves: bare hands	12.35	.0169
Cold gloves and mittens: leather gloves	12.15	.0188
Mittens: examination gloves	11.85	.0219
Cold gloves: examination gloves	10.50	.0418
Mittens: glove liners	10.45	.0428
Cold gloves and mittens: cold gloves	9.30	.0711
Cold gloves: glove liners	9.10	.0773
Mittens: flight gloves	9.00	.0806
Flight gloves: bare hands	8.90	.0840
Cold gloves and mittens: mittens	7.95	.1224
Cold gloves: flight gloves	7.65	.1370
Leather gloves: examination gloves	7.65	.1370
Glove liners: bare hands	7.45	.1475
Glove liners and leather gloves: examination gloves	6.30	.2203
Leather gloves: glove liners	6.25	.2240
Examination gloves: bare hands	6.05	.2391
Mittens: glove liners and leather gloves	5.55	.2800
Glove liners and leather gloves: glove liners	4.90	.3400
Leather gloves: flight gloves	4.80	.3499
Mittens: leather gloves	4.20	.4133
Cold gloves: glove liners and leather gloves	4.20	.4133
Glove liners and leather gloves: flight gloves	3.45	.5014
Cold gloves: leather gloves	2.85	.5786
Flight gloves: examination gloves	2.85	.5786
Flight gloves: glove liners	1.45	.7774
Glove liners: examination gloves	1.40	.7849
Cold gloves: mittens	1.35	.7924
Glove liners and leather gloves: leather gloves	1.35	.7924

[a]Mean of one glove group compared with a mean of another glove group (one minus another).
[b]The standard error of the mixed-model analysis of variance was 5.12 for the mean difference.

Table 2 *Time to Determination of Bleeding Control by Glove Group, Using Dunnett Method*[a]

Glove Group	Absolute Difference Minus Least Significant Difference (seconds)	p Value[b]
Cold gloves and mittens	12.13	<.0001
Mittens	4.177	.0043
Cold gloves	2.827	.0102
Leather gloves	−0.02	.0506
Glove liners and leather gloves	−1.37	.0976
Flight gloves	−4.82	.3783
Glove liners	−6.27	.5750
Examination gloves	−7.67	.7759
Bare hands	−13.7	1.000

[a]Dunnett method was used to calculate the absolute difference between the mean of each experimental group and the mean of the control group. If positive, the absolute difference minus the least significant difference (LSD) determined that the experimental group mean was more apart than the LSD from the control group mean and, therefore, was significantly different.
[b]Values are significant at $p < .05$.

For devices, U4-1 and U4-2 were slowest, and U1-1 and U2-2 were fastest. Devices U2-1, U2-2, and U3-1 were second fastest, and U3-1 and U4-2 were second slowest. Again, user effects dominated those of devices: intrauser results were consistently in the same level, although some devices also were in adjacent levels.

Overall Time: Unwrapping Time Plus Trial Time

The mean overall time (i.e., time to unwrap the tourniquet through time to trial completion) was 84 ± 35.6 seconds (median, 77 seconds; minimum, 32 seconds; maximum, 234 seconds; range, 202 seconds). Thus, there was a sevenfold range in overall times.

For users, the results followed same pattern as time to determination of bleeding control. The analysis showed that 61% of the variance of results in overall time could be attributed to the users.

For gloves, again, bare hands and examination gloves were in the fastest level with glove liners and flight gloves, whereas cold gloves layered under mittens were alone in the slowest level. Overall times with thicker gloves were slower. By the Dunnett method, five glove groups (cold gloves layered under mittens; cold gloves; mittens; leather gloves; and leather gloves and glove liners) had means that were significantly slower than that of bare hands ($p < .0458$, all five).

For devices, U4-1 and U4-2 were slow, and U1-1 and U2-2 were fast. Devices U2-1, U2-2, and U3-1 constituted the midlevel. Thus for devices, intrauser results were consistently in the same level, except those of user 2, who had devices in adjacent levels.

Tourniquet Pressure

The mean tourniquet pressure was 203mmHg ± 18.0mmHg (median, 205mmHg; minimum, 140mmHg; maximum, 274mmHg; range, 134mmHg; twofold range in pressure). Tourniquets were loose (categorically low pressure) in 15 tests; tight use (categorically high pressure) occurred in two tests. Of the 18 trial status failures (i.e., unsatisfactory result), 17 (94%) were due to pressure problems.

Pressure amplitude results for users 1, 2, and 3 were in the high level; those of users 2 and 4 were in the low level. Eight percent of the variance of results in tourniquet pressure could be attributed to the users. Users 1 through 4 had two, four, four, and five tests with loose tourniquets, respectively, whereas only user 1 had tests ($n = 2$) with tight tourniquets (high pressure). Of these 17 tests with pressures either too high or too low, eight occurred in the user's first half of uses and nine occurred in the second half.

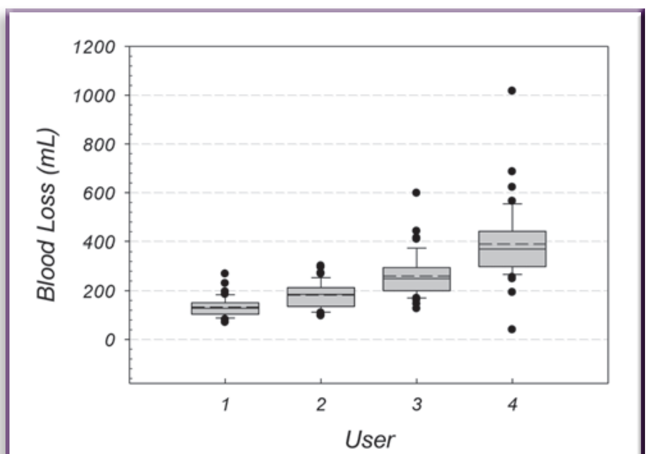
For gloves, Dunnett method showed that no mean was significantly different than that of bare hands ($p > .1586$, all nine). Among 17 tests with loose tourniquets, the count was two for bare hands, three for flight gloves, three for mittens, three for glove liners, two for leather gloves, one for glove liners layered under leather gloves, and three for cold gloves layered under mittens. The two tests with tight tourniquets were with bare hands and flight gloves.

For devices, the two levels of pressure amplitude had five devices each.

Blood Loss

The mean blood loss was 241 ± 18.0mL (median, 207.5mL; minimum, 40mL; maximum, 1017mL; range, 977mL; Figure 1). Blood loss volumes ranged 25-fold, the largest variance of the study.

Figure 1 *Blood Loss by User.*



The vertical box plots depict the 25th percentile as the box bottom, 75th percentile as the box top, 5th percentile as the down bar, 95th percentile as the up bar, the dashed line as the mean, and the solid line as the median.

Users 1 and 2 were in the low level, user 3 was in the midlevel, and user 4 was in the high level. The analysis showed that 68% of the variance of results in blood loss could be attributed to the users. In regression by use number, users showed no or mild learning ($R^2 < .3503$, all four).

For gloves, blood loss was lowest when bare hands were used and highest when cold gloves layered under mittens were used, but each level had three or five groups. By the Dunnett method, means of three glove groups—cold gloves layered under mittens, mittens, and cold gloves—were significantly higher than that for bare hands ($p < .0245$, all three). Blood losses were worsened by wearing gloves as compared with using bare hands. For these three groups, gloves worsened blood loss by 188mL, 116mL, and 124mL, respectively.

For devices, U4-1 was in the highest level, U4-2 was second highest, and U1-1, U2-1, and U2-2 were lowest. Devices U2-2 and U3-1 were in the second lowest level. User effects again dominated device effects: intrauser results by device were consistently in the same level, except those of user 4, who had a device alone in the two highest levels.

Comments of Tourniquet Users

Comments of users were developed into relevant tips for training tourniquet use (Table 3).

Table 3 *Training Tips as Gathered From Experience During the Study*

On average, performance while wearing thin gloves like examination gloves or flight gloves is similar to using bare hands.
On average, performance while wearing thick gloves like cold weather gloves is worse and slower than bare hands.
Novices should learn tourniquet use with bare hands before learning use with examination gloves.
To help novices initially tension the band for their patient: "Pull like their life depends on it!"
Advanced beginners should practice mostly with the glove type needed most often in their setting.
Competent tourniquet users should strive for familiarity with use of a few types of gloves.
Proficient tourniquet users should strive for familiarity with use of several types of gloves.
Experts should gain experience in use of all glove types relevant to their clients.
Advanced beginners need to know that actual assessments take longer in care than in training.
Novices judged band tension to be a surrogate for pressure, but it is a poor, unreliable surrogate.
Overconfidence of novices lessened as they accrued experience.
Pressure variance was small because users aimed to apply pressure within a narrow range.
Continuous metrics like blood loss tend to be sensitive to user, glove, and device effects.
Categorical metrics like trial status tend to be insensitive to user, glove, and device effects.
Course directors should choose performance metrics carefully after considering their merits.
Instructors should differentiate performance of a class (e.g., average) from that of an individual.
Training directors should check their course materials for glove-related content.
Medical directors in law enforcement or military units should check glove practices locally.
Authors of first aid lessons, curricula, and books should consider glove guidance.
Expert instructors may occasionally point out user technique and its outcome as cause and effect.
People save people. The tourniquet is just a tool. It's not magic. You, the user, can bring magic.
Emphasize the quality of training to optimally prepare users to perform at their best.
To optimize clinical outcomes, optimize training of users through preparation of instructors.
Users showed no or mild learning; glove effects may be resistant to accrual of user experience.
Test-to-test learning by individuals as data points was a bumpy road. To err is human.
Learning curves as best-fit lines often show smooth improvement as users accrue experience.
Extreme performances (e.g., failures) offered ideal opportunities for teachable moments.
Errors: tourniquet put atop a wound, and pulse felt with end of fingertip (volar pad is better).
Failure to assess bleeding, tourniquet looseness, or pulse status are teachable moments.
Failures that occur only late indicate that novices may not learn fully until after some failures.
Late mistakes: some things may be best learned by failing. Boundaries become clearer.
Gloves may increase risk of a common error: inadvertently applying a loose tourniquet.
A mix of good and bad performances may be optimal for learners if instructors capitalize well.
Good judgment comes from bad experience—assuming that we learn.
Thick gloves may dull hand sensation of how hard the band is pulled or the windlass twisted.
For tourniquet use at a sport stadium, doff your glove: that giant "We're Number 1!" foam finger.

(continues)

Discussion

The user often had major effects on performance. Among most continuous variables (i.e., time to determination of bleeding control, trial time, overall time, and blood loss), most of the variance (62%, 55%, 61%, and 68%, respectively) could be attributed to the users. In simulated use of a tourniquet, user effects were consistent with prior simulation studies and were common among performance metrics of continuous variables like blood loss.[22–25] Repeated studies have shown both direct and supportive evidence of impactful effects of the user for time to stop bleeding and blood loss, which affect simulated patient outcomes meaningfully.[26–34]

First aid authorities have asked for evidence associating user interventions with patient outcomes.[2,3,4] We reported such evidence from the Baghdad surge when the tourniquets of unchanging designs were used , but user skill improved as users improved in their control of bleeding for patients despite fewer tourniquets per limb being used; thirteen metrics of improved performance were tallied including: increased proportion of limbs with only one tourniquet needed, increased proportion of limbs with hemorrhage control by effective tourniquet use, and increased proportion of casualties with tourniquets used before shock onset.[36] However, such evidence is considered weak because only strong studies like controlled trials can yield strong evidence. We have reported analyses of user effects on intervention performance, and we more easily see user effects when interuser performance varies widely.[22–25,35] We analyzed user effects because the engines of caregiving are humans. We call the humans of our interest a user set, a group of people supporting the end-user of a tourniquet including assistants, instructors, first aid course directors, and others. The user set members may be individually suitable for study such as the learning curve of an instructor (JFK).[37] Furthermore, one of us (JFK) as an editor has asked more frequently for user effects to be reported in relevant submissions. Also, one of us (JFK) as a presenter to the Committee on Tactical Combat Casualty Care (September 7, 2016; College Park, Georgia) has challenged the community itself to expect or even demand user effect reporting in applicable studies.

Glove effects on performance were found consistently with three of eight glove types. Furthermore, performance times (i.e., time to hemorrhage control, trial time, overall time) with thicker gloves were generally slower than those with thinner gloves. The thinnest glove type, examination gloves, resulted in performance much like bare hands, whereas the thickest glove type, cold gloves layered under mittens, was significantly outperformed by bare hands. Glove effects were negative by slowing and worsening performance, and three groups (cold gloves, mittens, and cold gloves layered under mittens) often had significant effects, whereas others, like examination gloves, flight gloves, and glove liners, had no significant effects. For time to determination of bleeding control and blood loss, the glove effects for each of these same three groups were worse than bare hands.

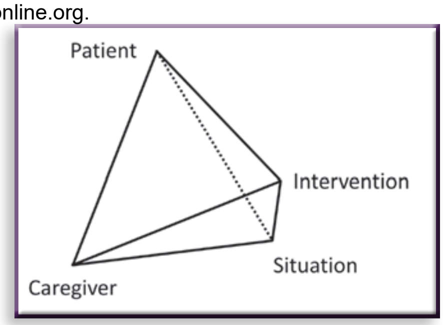
Actionable insights about gloves include the following: (1) instructors can underscore that, on average, first aid performance while already wearing examination gloves is similar to performance with bare hands; (2) tactical instructors can underscore that, on average, first aid performance while already wearing tactical gloves like flight gloves is similar to performance with bare hands; and (3) instructors can inform users that, on average, performance is worse with thicker gloves like cold weather gloves. However, in this study, the time to don gloves was not studied. Situations regarding gloves in standard precautions are outlined in World Health Organization guidance,[10] although the guideline is hospital oriented.

Device effects in use of tourniquets were found only for continuous metrics and were minor because they were often dominated by user effects.

The US Army reported in 2016 a new concept of tourniquet use as four dynamically interrelated components: patient, caregiver, situation, and intervention.[21] Interaction among these components was represented schematically as a pyramid (Figure 2). Corners represented components and edges represented relationships between components. Each component can change, and any change may affect any other component. The pyramid alters the perception from just seeing the tourniquet to looking at each component and at each interaction between components. It is easy for people to repeat that tourniquets save lives.[38,39] Tourniquets do not save people. People save people. A person uses a tourniquet. A tourniquet is just a tool. It is not magic. In the end, lifesaving is about people. When we demystify tourniquets in this way for caregivers, they are empowered as they realize that it makes sense, and they can learn this new skill like they learned prior skills. Furthermore, we paraphrase what educators have told us about the pyramid idea, "Well, duh! Users are the focus and need help preparing for care. That's why education exists." The pyramid is a general way to understand best care, and tourniquet use is one intervention with substantial evidence illustrating such understanding.

The limitations of this study are based in its design as laboratory simulation and not caregiving in the wild. The findings of this study pertain to the present methods, gloves, users, and tourniquet model, so readers should not extrapolate its findings beyond that. The numbers of users, glove types, and tourniquet devices were limited, and so findings are not fully generalizable. This study was a first attempt to compare glove types that may be used under different military situations and how gloves affect tourniquet performance as applied by users with different levels of experience. Performance was biased toward user 1 because he owned the gloves, had the best fit, and was most experienced user.

Figure 2 *Four Components of Best Care.*



Best care can be seen as that type of pyramid with only four faces, each of which is a triangle, as shown in the diagram. For example, tourniquet caregiving includes dynamic interplay of its components: a patient, a caregiver, a situation, and an intervention, as represented in the pyramid. Each corner is a component, and each edge is a potential interaction between components. Each component can change, which may alter the status of any other component. In tourniquet use, the first change sought is in the patient: control of bleeding. The patient changes over time because of the intervention (tourniquet use) as the limb under the tourniquet is compressed and gets smaller. A limb becoming smaller under the tourniquet over time can cause the wound to restart bleeding, another patient change. Such another change indicates a need for the caregiver to periodically recheck the patient and the tourniquet to detect rebleeding early for prompt correction, such as by tightening the tourniquet more. This pyramid organizes many observations in caregiving.

Future directions for scholarly work are many. A literature review of glove science, including textile and garment sciences, may find information relevant to operational medicine. The operational medicine community may develop subject matter experts in topics such as glove science (e.g., personal protective equipment topic assigned to the gear guy as a committee's point man), skill development education, and talent management. In this study, pressures were problematic yet varied little by user; additional research may lead to an explanation. Other directions are listed in Table 4.

Table 4 *Other Directions for Research*

Control groups can be either negative (bare hands) or positive (examination gloves).
Survey instructors and course directors for precautions practiced, problems with compliance, and awareness challenges (e.g., comprehension of precaution guidelines or glove science).
User performance assessments may be useful, especially if conducted locally.
Study time to don or doff gloves, performance effects, and benefits and risks to user and patient.
Gloves as fomites may be worthy of study.
Other first aid interventions may have user effects worthy of analysis.
Videotape survey of student compliance with precautions during classes.
Measure duration of assessments of wounds, tourniquets, pulses, bleeding, and patients.
Measure torques of rod required by hand dominance, sex, age, and number of hands used.
Study decisions or judgments under uncertainty while rendering first aid.
Study the qualities of supervision of users.
Study space-suit gloves, firefighter gloves, nuclear-biological-chemical gloves, military cold-weather gloves, and medieval chainmail layered under armored gauntlet gloves among jousting knight reenactors.

Conclusion

In this study of simulated first aid with tourniquets in control of bleeding, users had major effects on most metrics of performance, glove effects were significant for a few glove groups, and tourniquet device effects were found only for continuous metrics and were often dominated by user effects. Thinner gloves generally yielded better and faster results than thicker gloves.

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Disclaimer

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Disclosure

The authors declare no conflicts of interest.

Author Contributions

J.F.K., J.K.A., and M.A.D. conceived and designed the study; J.F.K. and V.K.M. resourced, managed, and oversaw the study; J.F.K., V.K.M., C.D.L., and M.A.D. collected data; J.F.K., J.K.A., and C.D.L. analyzed data; all authors participated in writing; and J.F.K. led production. All authors approved the final version of the manuscript.

References

1. **Pons PT, Jacobs L.** Save a life: What everyone should know to stop bleeding after an injury. http://www.bleedingcontrol.org/~/media/bleedingcontrol/files/stop%20the%20bleed%20booklet.ashx. Accessed 8 September 2017.
2. **Markenson D, Ferguson JD, Chameides L, et al.** Part 13: First aid: 2010 American Heart Association and American Red Cross International Consensus on First Aid Science With Treatment Recommendations. *Circulation*. 2010;122(16 Suppl 2):S582–605.
3. **Zideman DA, Singletary EM, De Buck ED, et al.** Part 9: First aid: 2015 International Consensus on First Aid Science with Treatment Recommendations. *Resuscitation*. 2015;95:e225–e261.
4. **Singletary EM, Charlton NP, Epstein JL, et al.** Part 15: First aid: 2015 American Heart Association and American Red Cross guidelines update for first aid. *Circulation*. 2015;132(18 Suppl 2):S574–S589.
5. **Committee on Trauma, American College of Surgeons.** How to stop the bleed. http://www.bleedingcontrol.org/resources/how-to-stop-the-bleed. Accessed 8 September 2017.
6. **Ritchie L, McIntyre J.** Standardising infection control precautions. *Nurs Times*. 2015;111(38):17–20.
7. **US Centers for Disease Control and Prevention.** Guidance for the selection and use of personal protective equipment (PPE) in healthcare settings. https://www.cdc.gov/hai/pdfs/ppe/ppeslides6-29-04.pdf. 2016. Accessed 8 September 2017.
8. **Udasin IG, Gochfeld M.** Implications of the Occupational Safety and Health Administration's bloodborne pathogen standard for the occupational health professional. *J Occup Med*. 1994;36(5):548–555.
9. **Twitchell KT.** Bloodborne pathogens. What you need to know—part I. *AAOHN J*. 2003;51(1):38–45; quiz 46–47.
10. **World Health Organization.** Aide-memoire: infection control standard precautions in health care. http://www.who.int/csr/resources/publications/4EPR_AM2.pdf. Accessed 8 September 2017.
11. **Kragh JF Jr, Aden JK 3rd, Lambert CD, et al.** Unwrapping a first aid tourniquet from its plastic wrapper with and without gloves worn: a preliminary study. *J Spec Oper Med*. 2017;17(3):27–36.
12. **Ladyshewsky RR, Hopper D, Abid S, et al.** The use and practice of body substance precautions in sports physiotherapy. *Aust J Physiother*. 1996;42(2):99–107.
13. **Geng Q, Chen F, Holmér I.** The effect of protective gloves on manual dexterity in the cold environments. *Int J Occup Saf Ergon*. 1997;3:15–29.
14. **Drabek T, Boucek CD, Buffington CW.** Wearing the wrong size latex surgical gloves impairs manual dexterity. *J Occup Environ Hyg*. 2010;7:152–155.
15. **Dianat I, Haslegrave CM, Stedmon AW.** Methodology for evaluating gloves in relation to the effects on hand performance capabilities: a literature review. *Ergonomics*. 2012;55:1429–1451.
16. **Drabek T, Boucek CD, Buffington CW.** Wearing ambidextrous vinyl gloves does not impair manual dexterity. *J Occup Environ Hyg*. 2013;10:307–311.
17. **Mylon P, Lewis R, Carré MJ, Martin N.** A critical review of glove and hand research with regard to medical glove design. *Ergonomics*. 2014;57:116–129.
18. **Eustis TC, Wright SW, Wrenn KD, et al.** Compliance with recommendations for universal precautions among prehospital providers. *Ann Emerg Med*. 1995;25(4):512–515.
19. **Picheansanthian W, Chotibang J.** Glove utilization in the prevention of cross transmission: a systematic review. *JBI Database System Rev Implement Rep*. 2015;13(4):188–230.
20. **Phillips AM, Birch NC, Ribbans WJ.** Protective gloves for use in high-risk patients: how much do they affect the dexterity of the surgeon? *Ann R Coll Surg Engl*. 1997;79(2):124–127.
21. **Kragh JF Jr, Dubick MA.** Battlefield tourniquets: lessons learned in moving current care toward best care in an Army Medical Department at war. *US Army Med Dep J*. 2016;2–16:29–36.
22. **O'Conor DK, Kragh JF Jr, Aden JK 3rd, et al.** Cat on a hot tin roof: mechanical testing of models of tourniquets after environmental exposure. *J Spec Oper Med*. 2017;17(1):27–35.
23. **Clumpner BR, Polston RW, Kragh JF Jr, et al.** Single versus double routing of the band in the Combat Application Tourniquet. *J Spec Oper Med*. 2013;13(1):34–41.
24. **Polston RW, Clumpner BR, Kragh JF Jr, et al.** No slackers in tourniquet use to stop bleeding. *J Spec Oper Med*. 2013;13(2):12–19.
25. **Davinson JP, Kragh JF Jr, Aden JK 3rd, et al.** Laboratory testing of emergency tourniquets exposed to prolonged heat. *J Spec Oper Med*. 2015;15(1):34–38.
26. **Altamirano MP, Kragh JF Jr, Aden JK 3rd, et al.** Role of the windlass in improvised tourniquet use on a manikin hemorrhage model. *J Spec Oper Med*. 2015;15(2):42–46.
27. **Kragh JF Jr, Geracci JJ, Parsons DL, et al.** Junctional tourniquet training experience. *J Spec Oper Med*. 2015;15(3):20–30.
28. **Dubick MA, Kheirabadi BS, Kragh JF Jr.** Recent technological advances in hemorrhage control for improved survival from combat wounds. *Proc of NATO RTO Symposium on Emerging Technological Advances in Tactical Casualty Care*. 2015;STO-MP-HFM-249:23-1 to 23-14.
29. **Gibson R, Aden JK 3rd, Dubick MA, et al.** Preliminary comparison of pneumatic models of tourniquet for prehospital control of limb bleeding in a manikin model. *J Spec Oper Med*. 2016;16(2):21–27.
30. **Gibson R, Housler GJ, Rush SC, et al.** Preliminary comparison of new and established tactical tourniquets in a manikin hemorrhage model. *J Spec Oper Med*. 2016;16(1):29–35.
31. **Kragh JF Jr, Aden JK 3rd, Shackelford S, et al.** Preliminary measures of instructor learning in teaching junctional tourniquet users. *J Spec Oper Med*. 2016;16(2):13–15.
32. **Kragh JF Jr, Moore VK 3rd, Aden JK 3rd, et al.** Short report comparing generation 6 versus prototype generation 7 Combat Application Tourniquet® in a manikin hemorrhage model. *J Spec Oper Med*. 2016;16(1):14–17.
33. **Kragh JF Jr, Mabry RL, Parsons DL, et al.** Learning curves of emergency tourniquet use exploring for utility in training. *J Spec Oper Med*. 2016;16(4):7–14.
34. **Bequette BW, Kragh JF Jr, Aden JK 3rd, et al.** Belts evaluated as limb tourniquets: BELT study comparing trouser supporters used as medical devices in a manikin model of wound bleeding. *Wilderness Environ Med*. 2017;28(2):84–93.
35. **Kragh JF Jr, Aden JK 3rd, Shackelford S, et al.** Assessment of Trainer Skill to Control Groin-Wound Bleeding: Use of Junctional

Tourniquet Models on a Manikin. *J Spec Oper Med*. 2017;17(2):39–48.

36. **Kragh JF Jr, Beebe DF, O'Neill ML, et al.** Performance improvement in emergency tourniquet use during the Baghdad surge. *Am J Emerg Med*. 2013;31(5):873–875.
37. **Kragh JF Jr, Aden JK 3rd, Shackelford S, et al.** Preliminary Measures of Instructor Learning in Teaching Junctional Tourniquet Users. *J Spec Oper Med*. 2016;16(2):13–15.
38. **Knox AGS.** Shark attacks on the rise: how tourniquets save lives. http://edmdigest.com/preparedness/shark-attacks-tourniquets/. Accessed 8 September 2017.
39. **CBS Broadcasting Inc.** Tourniquet credited with saving life of officer wounded in shootout. http://boston.cbslocal.com/2016/10/13/boston-police-shooting-officer-matt-morris-tourniquet-saved-life-commissioner-william-evans/. Accessed 8 September 2017.

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