



Comparison of the effectiveness of CAT and SOFTT tourniquets – a pilot study.

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Formal Analysis - C
Funding Acquisition - D
Investigation - E
Methodology - F
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Software - I
Supervision - J
Validation - K
Visualization - L
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Writing (Review & Editing) - N
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ABSTRACT

INTRODUCTION: Armed conflicts around the world have been going on for centuries, with many casualties. The main cause of pre-hospital cardiac arrest in combat settings are external hemorrhages, which is why rapid response skills and appropriate equipment are so important. The aim of the study was to compare the effectiveness of Combat Application Tourniquet (CAT) and Special Operations Forces Tactical Tourniquet (SOFTT) tourniquets using human unfixed preparations under simulated bleeding conditions.

MATERIAL AND METHODS: Thirty active-duty soldiers of the Polish Army were included in the study. The study was divided into 4 stages. In the first stage, a short training session was conducted for the subjects on how to stop external hemorrhages using CAT and SOFTT tourniquets, and additionally, they filled out prepared questionnaires. The second stage involved a qualitative evaluation of participants' practical skills in applying CAT and SOFTT tourniquets under low-fidelity conditions. During the third stage, randomization was performed with a division into two subgroups and a test using human cadavers. Two examiners measured the timing of tourniquet application. In stage four, the subjects took a final survey to assess their level of satisfaction.

RESULTS: The study group consisted of 14 women (50%) and 14 men (50%). The group was divided into two subgroups. Group A applied the CAT tourniquet in a mean time of 38.13 seconds (SD ± 11.19), while B applied the SOFTT tourniquet in a mean time of 29.31 seconds (SD ± 7.18). Statistically significant differences were found between the two groups in terms of the achieved time of tourniquet fitting (Mann-Whitney test=54.5; p=0.049). A number of analyses were conducted using Pearson's r – correlation, showing no significant correlations in any of the groups between the score obtained and age (pA=0.426; pB=0.486), marital status (pA=0.145; pB=0.932), place of residence (pA=0.168; pB=0.534), education (pA=0.523; pB=0.935), or military rank held (pA=0.225; pB=0.252).

CONCLUSIONS: SOFTT-type tourniquet is more effective in application than CAT-type tourniquet. Cadavers – human unfixed preparations – are a great tool for educating soldiers on stopping life-threatening hemorrhages under simulation conditions.

KEY WORDS: Tourniquet, hemorrhage, CAT, SOFTT, cadaver, training, soldier

INTRODUCTION

Tactical Combat Casualty Care (TCCC) are guidelines based on practices collected over many years concerning how to provide care for armed conflict victims around the world. These guidelines, first published in 1996 in the journal *Military Medicine*, outline patterns for battlefield emergency responders [1]. Under combat conditions, self-safety, personal protective equipment as well as the ability to adapt to the current situation play the most important role. Operation during enemy aggression must also be based on soldiers' adaptation to light and sound discipline while meeting TCCC objectives [2]. On the battlefield, deaths incurred as a result of injuries with external hemorrhages present account for the largest proportion of deaths. It is a reversible cause of death that results from a break in the continuity of the skin or mucous membranes and extends deep into the tissues. Soldiers are equipped with protective gear – vests, Kevlar helmets – but these only protect their torsos, leaving their limbs vulnerable to injury. Hemorrhage is considered to be the loss of 1.5 mL/kg b.w./min in 20 minutes and 150 mL/kg b.w./min of blood in one hour [3]. It is important then to remember the acronym ABC when rescuing the victim, which changes its order to CABC in the case of visible hemorrhage, where in both cases: A means airway (airway patency), B – breathing, C – circulation [4].

Keep in mind that there are numerous ways to stop hemorrhages. These can include manual compression, hemostatic dressings, as well as tourniquets [5]. Bleeding from extremities that cannot be controlled with manual pressure or with hemostatic dressings qualify for a tourniquet. The TCCC guidelines have taken the lead in promoting the aggressive use of tourniquets to stop life-threatening hemorrhages [6]. It is advisable for each soldier to have individual bandages in their personal equipment, as well as a tourniquet, which should be prepared for possible action and be in an easily accessible place so that it can be reached with both left and right hands [7,8]. There are many types of tourniquets, including CAT and SOFTT. Both of these tourniquets, placed on the upper or lower extremity, have the same effect on the blood vessels and, by tightening them, lead to the formation of a thrombus and, as a result, the cessation of bleeding. There is also no significant difference in their ability to maintain the absence of a pulse even after many maneuvers [9]. However, achieving such a therapeutic effect after applying a tourniquet requires knowledge and skill on the part of the person undertaking its use. Human unfixed preparations are an excellent tool for consolidating manual skills in applying a tourniquet in a simulated bleeding situation. The use of the cadaver allows not only to train manual skills, but also influences the assessment of the mental aptitude of soldiers who may one day have to face the need to help wounded persons in real combat conditions.

The aim of the study was to compare the effectiveness of CAT and SOFTT tourniquets under battlefield conditions, as well as to assess the benefits of using human unfixed preparations during training based on subjects' satisfaction ratings.

MATERIAL AND METHODS

The study, along with the training, was conducted at the Medical Simulation Center at the Faculty of Medical and Health Sciences of the Siedlce University of Life Sciences and Humanities in the second half of 2022. They were divided into 4 stages in order to obtain a uniform baseline level of the study group's skills, thus leveling out the confounding factor of the final result.

During the first stage, the subjects filled out a preliminary questionnaire with sociodemographic data, as well as consented to participate in the study. Each participant also signed an informed consent to work with human unfixed specimens and a statement regarding ethical responsibilities. In addition, at this stage, a class was conducted for soldiers on stopping external hemorrhages using CAT and SOFTT tourniquets in accordance with International Trauma Life Support (ITLS) guidelines, which included a theoretical and practical part. The second stage involved a qualitative evaluation of participants' practical skills in applying CAT and SOFTT tourniquets under low-fidelity simulation conditions. For this purpose, a phantom lower limb without injuries and simulated body fluids were used. At this stage, the subjects had the opportunity to learn about the construction of tourniquets and the procedure for applying them. Stage three involved a randomized division into two groups with a top-down assignment of the tourniquet type to be used (group A – CAT tourniquet, group B – SOFTT tourniquet). A cadaver test was conducted, during which two examiners measured the time it took to successfully apply tourniquets, i.e. until the external hemorrhage from the lower limb had completely stopped. The fourth stage was an exit survey assessing participant satisfaction, subjective feedback concerning substantive values and open-ended conclusions. A five-point Likert scale was used for evaluation.

The inclusion criteria consisted of full-time participation in the training, completion of documentation and questionnaires, as well as undertaking and completing the cadaver task. The study was approved by the bioethics committee (No. 19/2022 UPH Siedlce).

RESULTS

Study participants

While 30 soldiers of the Polish Army participated in the training, 28 people were eventually included in the study, as two people decided to quit when they entered the practical task using cadavers. The study group included 14 (50%) women and 14 (50%) men, with a mean age of 32.5 (SD $\pm$ 9,32). The majority of participants are residents of rural areas (57.14%; n=16) compared to urban areas (42.86%; n=12). Participants mostly share a household with their parents (32.14%, n=9), as well as with a partner (17.86%; n=5) or live alone (17.86%; n=5). The marital status clarified as follows:

- single: 42.86% (n=12);
- married: 46.43% (n=13);
- divorcee: 7.14% (n=2).

High school education at the time of the survey was declared by 53.57% (n=12) of the subjects, master's degree by 28.57% (n=8), and bachelor's degree by 17.86% (n=5). Among the participants were 14 (50%) privates, 6 (21.43%), E3 privates ("Private First Class"), 5 (17.86%) corporals, 2 (7.14%) second lieutenants and 1 (3.57%) master corporal (E5).

Tourniquet application time

Group A applied the CAT tourniquet in a mean time of 38.13 seconds (SD $\pm$ 11.19), while Group B applied the SOFTT tourniquet in a mean time of 29.31 seconds (SD $\pm$ 7.18). Both groups showed normality of variable distribution (Shapiro-Wilk "group A"= 0.939; p=0.373 and Shapiro-Wilk "group B"= 0.901; p=0.104) but non-parametric tests were used, because independent samples were conducted. There were statistically significant differences between the two groups in terms of the achieved time of tourniquet fitting (Mann-Whitney test=54.5; p=0.049) included in Figure 8.

A number of analyses were conducted using Pearson's r – correlation, showing no significant correlations in any of the groups between the score obtained and age ($p_A=0.426$; $p_B=0.486$), marital status ($p_A=0.145$; $p_B=0.932$), place of residence ($p_A=0.168$; $p_B=0.534$), education ($p_A=0.523$; $p_B=0.935$), or military rank held ($p_A=0.225$; $p_B=0.252$).

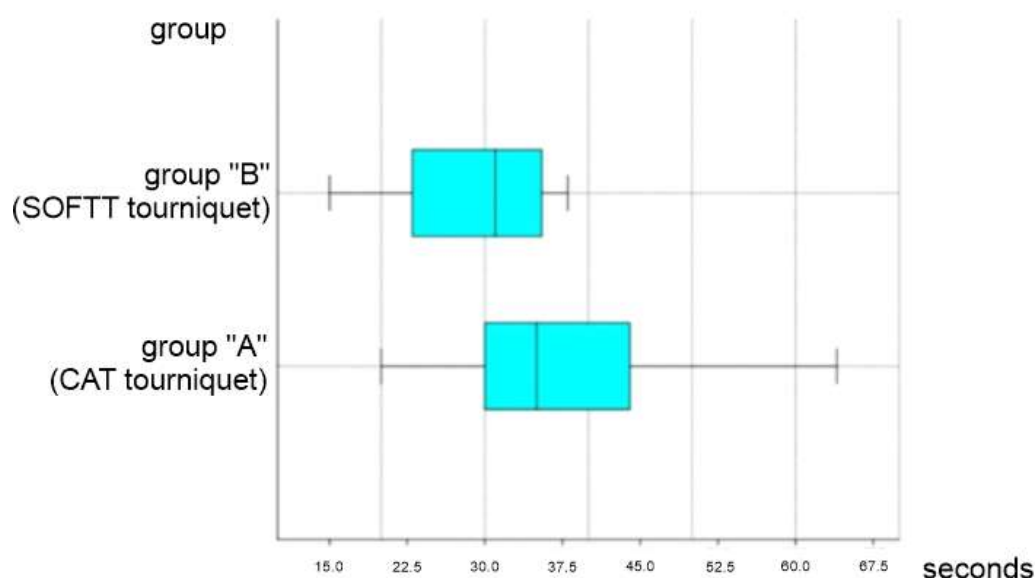
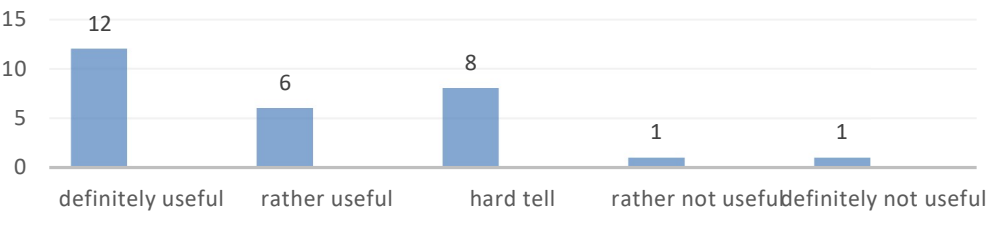
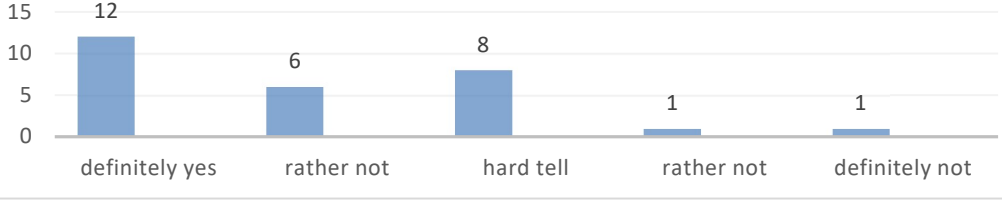
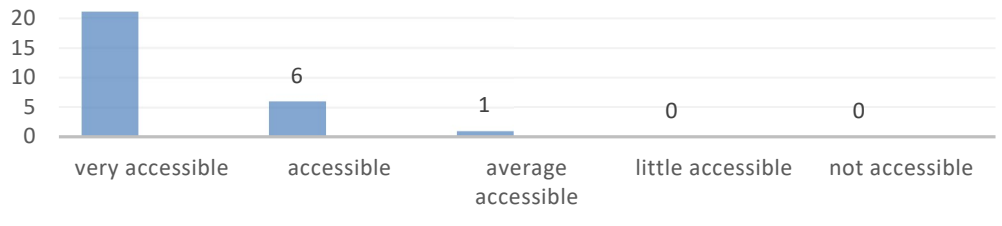
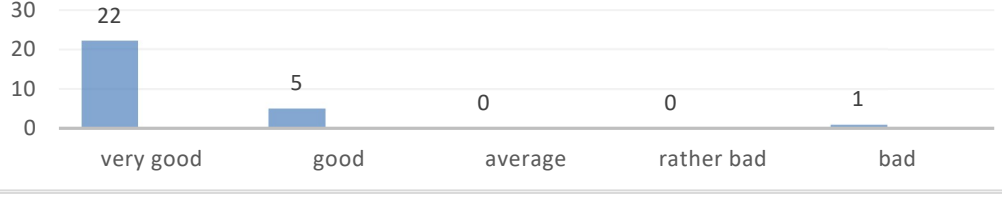
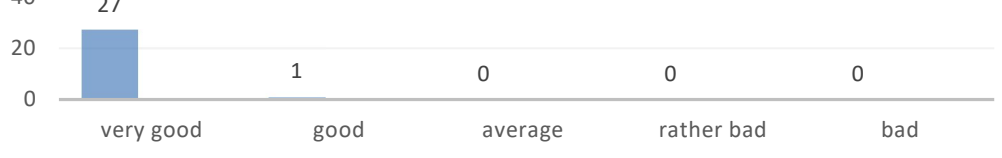


Figure 1. CAT and SOFTT tourniquet application time in the study groups.

Assessment of participant satisfaction

The trainees were asked ten questions, including two open-ended questions. First, they were asked for their assessment as to the scope of the material presented, and the range of responses included a five-point scale, where 5 meant "far too broad" and 1 meant "far too narrow". Twenty-three subjects answered by awarding three points, which was considered as an "adequate" rating.

Table 1. Satisfaction evaluation of trainees.

Aspect	Evaluation (n)												
The degree to which expectations of training are met	 <table border="1"> <thead> <tr> <th>Evaluation</th> <th>n</th> </tr> </thead> <tbody> <tr> <td>very good</td> <td>21</td> </tr> <tr> <td>good</td> <td>4</td> </tr> <tr> <td>sufficient</td> <td>2</td> </tr> <tr> <td>poor</td> <td>1</td> </tr> <tr> <td>insufficient</td> <td>0</td> </tr> </tbody> </table>	Evaluation	n	very good	21	good	4	sufficient	2	poor	1	insufficient	0
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good	4												
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poor	1												
insufficient	0												
Evaluating the usefulness of the acquired information in terms of improving one's own competencies and skills	 <table border="1"> <thead> <tr> <th>Evaluation</th> <th>n</th> </tr> </thead> <tbody> <tr> <td>definitely useful</td> <td>12</td> </tr> <tr> <td>rather useful</td> <td>6</td> </tr> <tr> <td>hard tell</td> <td>8</td> </tr> <tr> <td>rather not useful</td> <td>1</td> </tr> <tr> <td>definitely not useful</td> <td>1</td> </tr> </tbody> </table>	Evaluation	n	definitely useful	12	rather useful	6	hard tell	8	rather not useful	1	definitely not useful	1
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The degree of increased theoretical knowledge in the area discussed at the training course	 <table border="1"> <thead> <tr> <th>Evaluation</th> <th>n</th> </tr> </thead> <tbody> <tr> <td>definitely useful</td> <td>22</td> </tr> <tr> <td>rather useful</td> <td>6</td> </tr> <tr> <td>hard tell</td> <td>0</td> </tr> <tr> <td>rather not useful</td> <td>0</td> </tr> <tr> <td>definitely not useful</td> <td>0</td> </tr> </tbody> </table>	Evaluation	n	definitely useful	22	rather useful	6	hard tell	0	rather not useful	0	definitely not useful	0
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Four people awarded two points, meaning that the material presented was "too narrow" in their opinion. One person, on the other hand, felt that the material was "*far too narrow*". In the second question, participants had to indicate what was missing from the training. Most of the subjects did not answer this question, and according to the opinions of the others, it appeared that there was too little theory and practice during the training. Based on these responses, one can conclude that soldiers need adequate training that thoroughly covers the range of topics to be included.

There were no significant differences between the groups in the evaluation of the atmosphere of the course conducted ($p=0.316$), the training materials, ($p=0.796$), the form of the instructor's delivery of the content ($p=0.272$), the selection of didactic material ($p=0.729$), the acquisition of practical skills ($p=0.951$), and the fulfillment of trainee expectations concerning the training ($p=1$).

DISCUSSION

Many trauma-related deaths are preventable deaths, depending mainly on the level of knowledge of the responders and their mental predisposition. All of this is related to knowing and acting according to TCCC (Tactical Combat Casualty Care) guidelines [10]. The most important thing on the battlefield is to stop bleeding, which is the main cause of cardiac arrest among the injured. Tourniquets are one of the best tools to stop heavy bleeding. Every soldier has at least one tourniquet, placed in an easily accessible place. The use of tourniquets is a challenge even for specialized units, which is why it is so important to provide opportunities for training and regular implementation of this procedure [11,12,13]. In addition, sometimes one has to prepare own improvised tourniquet, and this also requires a range of knowledge, so that the tourniquet would do its job, stop bleeding, without increasing the tissue structure damage [14,15].

A study conducted by R. Schreckengaust, L. Littlejohn, and GJ. Zarow demonstrated that despite the impact of combat stress, CAT-type tourniquet achieves better time and also higher efficiency [16]. In a study by J. F. Kragh Jr et. al.: "Practical use of emergency tourniquets to stop bleeding in major limb trauma", CAT-type tourniquet also proved to be one of the most effective tourniquets, with a positive benefit-risk ratio with regard to survival benefit [17]. This proves that using tourniquets does not always lead to limb amputation, and that the timing of tourniquet hemorrhage stopping is not closely related to increased morbidity [17-20]. In a detailed analysis of a study conducted with soldiers, the SOFTT-type tourniquet was found to be more effective. Group A applied the CAT tourniquet in a mean time of 38.13 seconds ($SD \pm 11.19$), while Group B applied the SOFTT tourniquet in a mean time of 29.31 seconds ($SD \pm 7.18$).

Prepared human cadavers are a very good educational tool. This is evidenced not only by the study conducted with soldiers, but also by the research of many other authors, such as. Leszczyński P, Muraczyńska B, Wejnarski A, et al., who, in an article titled "*Improving the quality of training paramedics by means of cadavers - a pilot study*" demonstrate that using cadavers is an excellent way to teach practical competence in trauma assessment among students [21].

Similarly, in a study titled *"Cadaver as an educational tool increasing the effectiveness of Combat Application Tourniquet use in extremity injuries"*, authors indicated that training conducted on human cadavers improves the effectiveness of tourniquet application, once again proving that cadavers are a high-quality educational tool for practicing invasive procedures such as limb hemorrhage stopping [22]. Cadavers are also a great tool for learning how to auscultate pulmonary fields, and the study *"Cadaver as a didactic tool for auscultating lung sounds"* demonstrates that learning on phantoms is insufficient to achieve perfection in the efficiency of auscultating lung fields, whereas human cadavers are likely to allow that [23]. Similarly, exercises involving cadavers proved effective during a study conducted with a group of soldiers. They had the opportunity to come into contact with the real structure of the human lower limb, something that phantoms have not allowed in the past.

The simulated bleeding allowed soldiers to face the difficulties they might encounter in real combat conditions. It is completely different to apply a tourniquet on a phantom that is dry compared to a bleeding human limb, wherein the equipment very quickly becomes wet and therefore more difficult to use. On a daily basis, soldiers do not have the opportunity to improve their competency in applying tourniquets to cadaveric arms, as this method is not readily available to everyone and, in addition, is very expensive and requires adequate facilities [21-26]. It should also be noted that the soldier group had the opportunity to learn what medical simulation is all about, constituting an increasingly superior tool for educating medical personnel these days.

These exercises allowed the soldiers to gain confidence in their actions. The study also provided an opportunity to test the mental aptitude of soldiers. As it turned out during the test, two people decided to quit, the reason being the sight of a corpse. The sight triggered a block in the subconscious that proved to be an unbreakable barrier. Participants who opted out had not previously indicated a problem with putting the tourniquet on the phantom, unlike the human preparations, which caused aversion. Nonetheless, training using cadavers proved rewarding. The soldiers had the opportunity to confront and organize their existing knowledge of stopping life-threatening external hemorrhages. In the final survey, the majority of participants agreed that the tourniquet training and cadaver exercises were useful in terms of improving their own competence and skills, and would deepen their knowledge, with possible use not only at work but also in their private lives.

CONCLUSIONS

The SOFTT tourniquet takes less time to apply than the CAT tourniquet. The quality of tourniquet training for life-threatening hemorrhages is optimized through the use of human unfixed specimens (cadavers), resulting in high realism of medical simulation. In terms of providing aid on the battlefield, mastering techniques for securing hemorrhages from extremities, as well as selecting the right medical equipment, is crucial.

SUPPLEMENTARY INFORMATION

Funding: No fund was received related to this study.

Institutional Review Statement: The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Not applicable

Data Availability Statement: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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