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SHORT COMMUNICATION

COMBAT TOURNIQUET APPLICATION UNDER INCREASED G-FORCE

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Abstract: Data from the literature on Tactical Combat Casualty Care (TCCC, TC3) indicate that approximately 60% of all preventable deaths are caused by bleeding from the limbs [3]. Every soldier/officer is trained in the procedure for effective control of extremity hemorrhage using a tourniquet as part of self-aid and buddy aid on the battlefield. Application of a tourniquet is the only recommended intervention during the Care Under Fire (CUF) phase [4]. Numerous publications in the professional literature describe the use of tourniquets in various situations; however, most studies are conducted under conditions of normal gravitational acceleration. The authors did not identify any studies addressing the use of a tourniquet under conditions of increased G-force.

The present study evaluates the correctness of tourniquet application performed as self-aid under conditions of increased G-force, occurring, among others, during flights of high-maneuverability aircraft. The publication presents partial data collected between June 2024 and September 2025.

During the analyzed period, the study was conducted on a group of 27 participants (8 women and 19 men), consisting of civilians and soldiers. Participants applied a tourniquet three times using the self-aid method: first under normal gravitational conditions (1G), then in a human centrifuge at 2G and 3G. The time required to apply the tourniquet was measured at each stage of the study. The effectiveness of vascular occlusion was assessed by evaluating radial artery blood flow using Doppler ultrasound with a portable ultrasound device. A total of 190 application times were analyzed.

It was demonstrated that, regardless of G-force exposure, the time required to achieve effective occlusion with a tourniquet remained within limits ensuring effective control of hemorrhage from a major blood vessel.

Keywords: life-threatening hemorrhage, tourniquet application, G-force

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INTRODUCTION

Data from the literature on Tactical Combat Casualty Care (TCCC, TC3) indicate that approximately 90% of all battlefield deaths occur before the casualty reaches a field hospital. Among these, so-called preventable deaths can be distinguished, that is, deaths that would not have occurred if an appropriately rapid response had been provided by the casualty or by nearby personnel. Approximately 60% of all preventable deaths are caused by extremity hemorrhage [2,3]. In order to reduce this rate, every soldier/officer is trained in the procedure for effective control of extremity hemorrhage using a tourniquet as part of self-aid and buddy aid on the battlefield [4].

The use of a tourniquet, also referred to as a tactical tourniquet, is also recommended in the Tactical Emergency Casualty Care (TECC) guidelines for the civilian environment [6], which describe principles for providing aid to individuals in life-threatening conditions resulting from the use of weapons and combat means in civilian settings. Tourniquets are also used in civilian conditions by Emergency Medical Services (EMS) teams and in Hospital Emergency Departments (EDs). The Polish Medical Air Rescue service was the first in Poland to introduce the use of a CAT-type tourniquet in civilian conditions.

Two main determinants of success in controlling hemorrhage and saving the life of the injured person can be distinguished: the correctness of tourniquet placement and the time required to achieve hemostasis. A properly applied tourniquet should be placed over clothing or a uniform, as proximally as possible on the injured limb. The described method of tourniquet application applies to the Care Under Fire phase. The study described herein assumed tourniquet application during the Care Under Fire phase.

The intended outcome of these actions is compression of the arterial vessel, completely preventing blood flow and, consequently, external bleeding through the damaged vessel, that is, cessation of hemorrhage.

Table 1 presents the tourniquet application times applicable to soldiers.

Assessment of the effectiveness of tourniquet application is performed using Doppler analysis of the compressed vessel with portable ultrasound devices [5,7].

MATERIALS AND METHODS

The study received a positive opinion from the Bioethics Committee and has been conducted at the Military Institute of Aviation Medicine since June 2024. Healthy volunteers from both civilian and military environments participate in the study. All participants received an information sheet for study participants and provided written informed consent to participate in the study.

The present publication concerns the analysis of data collected between June 2024 and September 2025. The data presented were obtained from 27 participants, with a total of 190 measurements included in the analysis. The study participants were individuals aged 24 to 57 years, including 8 women and 19 men, with a BMI ranging from 18 to 36 kg/m^2, comprising 11 soldiers and 16 civilians. The study is ongoing, and analysis of additional results will be the subject of subsequent publications.

All participants were first trained in one-handed tourniquet application (using the dominant hand) on the "injured" contralateral upper limb, performing so-called self-aid. Subsequently, they applied the tourniquet three times under normal Earth gravity conditions (1G). Each time, the tourniquet application time and the effectiveness of arterial vessel occlusion were measured.

The same participants were then exposed to 2G acceleration aboard a human centrifuge. There, they also independently applied the tourniquet three times. In each case, the time required to apply the tourniquet was measured, and after completion of the centrifuge run, the effectiveness of the third tourniquet tightening was assessed.

Table 1. Individual training and combat standards of the Ministry of National Defense [1].

Assessment	Time of placement (soldier)	Time of placement (military medical personnel)
Very good	40 s	20 s
Good	50 s	30 s
Sufficient	60 s	40 s
Failure to meet the standard	> 60 s	> 40 s

The next stage involved tourniquet application by the same participants, still using the self-aid method, under 3G acceleration. Three attempts at tourniquet application were performed, with application time measured each time, and after completion of the centrifuge run, arterial vessel occlusion was verified.

Not all participants reached the 2G and 3G levels; the reasons for withdrawal from further participation in the study included nausea and dizziness experienced in the centrifuge. The participants did not belong to flight personnel, which may have contributed to a higher risk of these symptoms.

A total of 190 tourniquet application time measurements were obtained: 27 participants applied the tourniquet three times under 1G conditions, then 22 of them applied the tourniquet under 2G conditions, and finally 15 of them applied the tourniquet three times under 3G conditions.

The effectiveness of vessel occlusion was assessed by examining blood flow in the radial artery using Doppler ultrasound with a portable ultrasound device C10-TX (MyUSG – 3 in 1 WiFi, manufacturer: Konted) equipped with a wireless dual-sided probe (convex + linear + cardiac) in a dedicated vascular setting. To avoid assessment discrepancies, all examinations were performed by the same operator.

During the study, an innovative Polish RESQ tourniquet was used (Fig. 1).

Fig. 1. RESQ tourniquet.

RESULTS

The maximum tourniquet application time was 60 s (one participant dropped the tourniquet on the floor), while the minimum time was 8.1 s.

The mean application time across all measurements, divided by study stage, was as follows:

- under 1G load (81 applications), the mean tourniquet application time was 17.57 s;
- under 2G load (71 applications), it was 16.51 s;
- under 3G load (38 applications), it was 15.72 s.

The mean tourniquet application times for individual participants, as well as the overall mean for all participants at each stage of the study, are presented in Figures 2 and 3.

In every analyzed case, tourniquet application effectively stopped blood flow.

Analysis of mean application times using analysis of variance confirmed the absence of statistically

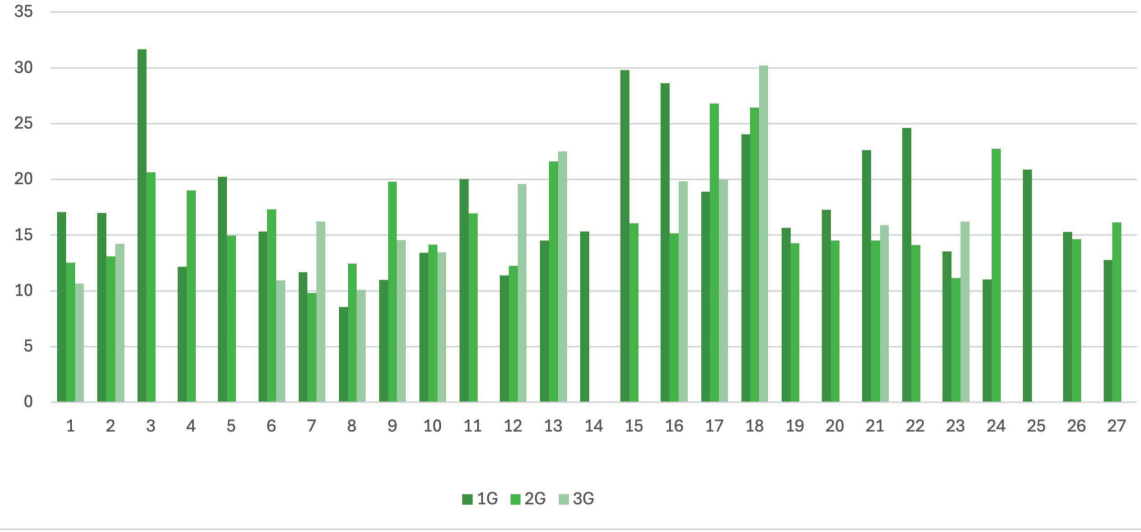

Fig. 2. Mean tourniquet application times for individual participants at each of the three stages of the study.

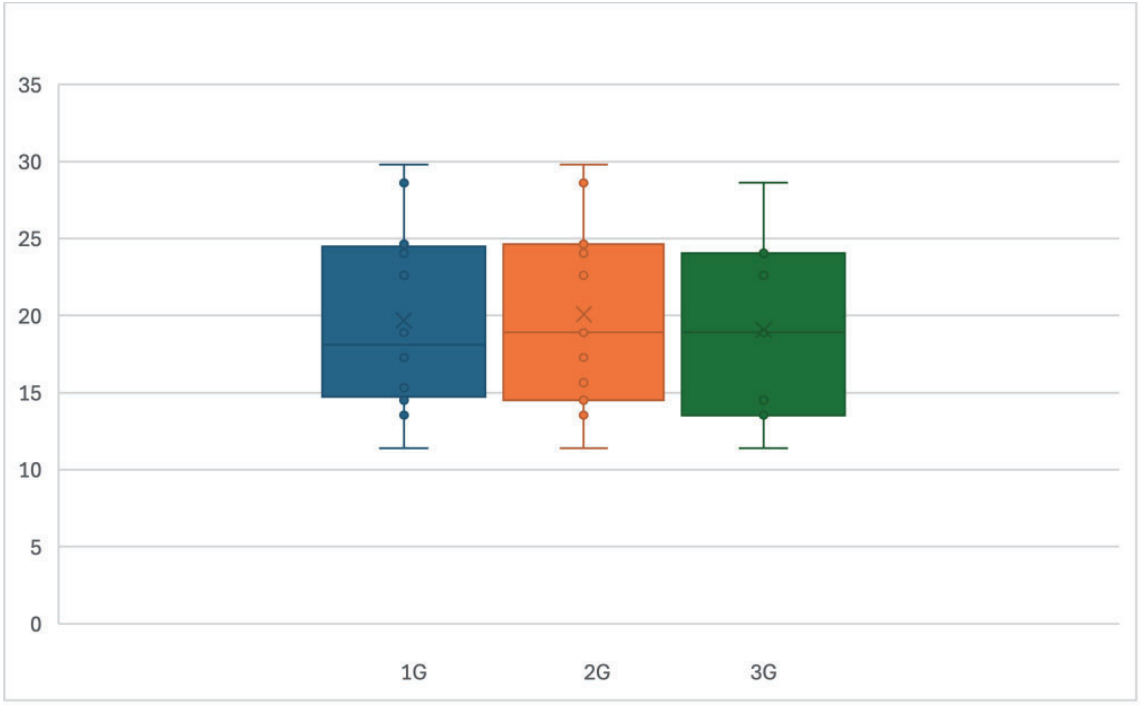

Fig. 3. Distribution of mean tourniquet application times at each of the three stages of the study.

significant differences between tourniquet application times without G-force exposure and under 2G and 3G conditions (p = 0.74).

A limitation of the study is the decreasing number of measurements due to participants' malaise during subsequent stages of the study. This is related to the operating mechanism of the human centrifuge, which may cause dizziness and nausea in some individuals.

Due to the relatively small amount of data, continuation of the study is necessary.

DISCUSSION AND CONCLUSIONS

Pilots of high-maneuverability aircraft constitute a group at particularly high risk of sustaining life-threatening injuries during combat missions. Situations such as hostile fire resulting in penetration of the cockpit and fuselage, ejection, or emergency landing may lead to pilot injuries requiring immediate tourniquet use.

At present, a tourniquet is not standard equipment for pilots of high-maneuverability aircraft. Given the ease and effectiveness of its use, including under G-force conditions, the authors believe that it should be included in the equipment of every pilot or aircraft during flight operations.

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AUTHORS' DECLARATION

Study Design: Magdalena Kozak, Krzysztof Kowalczuk. **Data collection:** Magdalena Kozak, Daria Sałacińska. **Manuscript preparation:** Magdalena Kozak, Daria Sałacińska, Katarzyna Sowa, Krzysztof Kowalczuk. The authors declare no conflict of interest.

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