OXFORD JOURNAL
OF STUDENT
SCHOLARSHIP

Evaluation of a manual, adjustable pressure device for bleeding control in low-resource and emergency settings

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ABSTRACT

Introduction: Uncontrolled bleeding is one of the leading causes of preventable deaths in the world, especially in low-resource and emergency settings. In Palestine, the West Bank, where access to hospitals and immediate healthcare is very limited, civilians can only hope to get access to basic first aid. Hence, reports from the World Health Organization (WHO) call for practical bleeding-control tools suitable for field use.

Existing methods, such as tourniquets, stop bleeding but can cause complications if used for prolonged periods, while improvised techniques using cloth or bandages often provide inconsistent pressure. This study evaluates a manually operated, adjustable device that applies direct, localized pressure to the wound using an inflatable pressure system while avoiding complete occlusion of simulated flow through the model. The device is worn around the affected limb and allows the pressure to be adjusted by the user depending on the severity of the injury.

Methods: A survey and experimental bench-testing approach was used. First, an online survey of 200 participants (mostly with first-aid/medical experience) to gather participants' perceptions of current bleeding control methods and their perceived need for and acceptance of the proposed device concept. Second, prototype testing using a gelatin-based wound model. Survey responses were analyzed, and prototype performance was assessed by measuring applied pressure, time to bleeding control, and the amount of simulated blood lost.

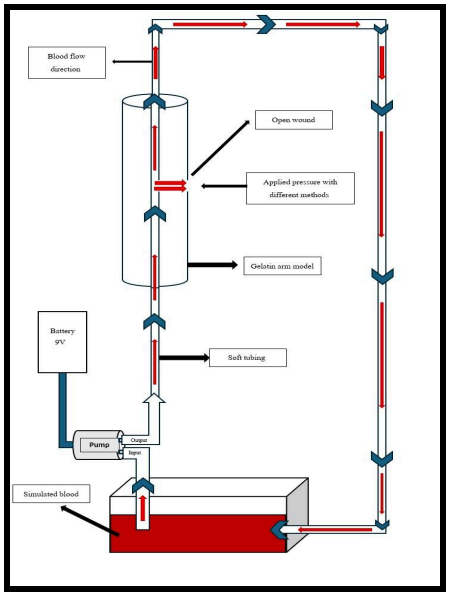


Figure (1): 2D model of the experiment

Results: Survey results indicated widespread support for the proposed device concept, with a majority expressing concern about tourniquet-related complications. Prototype testing showed that the device applied a mean of 134 ± 12 mmHg of stable pressure and reduced simulated bleeding while maintaining simulated flow in the model.

Conclusion: This study demonstrates promising preliminary benchtop feasibility of a manual, adjustable pressure device for bleeding control in controlled gelatin-model conditions, particularly as a concept designed for low-resource and conflict-affected settings. Additional validation with increasingly realistic models of bleeding is needed before any conclusions can be drawn about its clinical safety, efficacy, and potential role relative to established bleeding-control methods.

INTRODUCTION

Uncontrolled bleeding is one of the leading causes of death following a traumatic injury (Kauvar et al., 2006; Eastridge et al., 2012), especially in places where access to immediate health care and rapid professional medical response is very limited. Hemorrhages can become fatal within minutes if not treated properly, which is often before the patient can reach a hospital or a medical center (Eastridge et al., 2012), leaving civilians to deal with serious injuries with basic first aid and simple medical tools until professional medical care becomes available. Previous medical research suggests that a large number of hemorrhage-related deaths occur before hospital arrival (Kauvar et al., 2006; Eastridge et al., 2012), thus underlining the crucial need for early intervention in the prehospital settings. Multiple global health organizations such as WHO highlight the need for easy-to-use, affordable, and reliable medical tools

suitable for field use (World Health Organization, 2005), particularly in places where conflict, infrastructure, or medical supplies are major limitations.

In many low-resource and conflict-affected areas, delays in emergency care are caused by many factors, such as restrictions on movement, lack of medical supplies, and limited access to professional care (Henry & Reingold, 2012; World Health Organization, 2005). These challenges have been documented in many Low- and Middle-Income Countries (LMICs) and conflict-affected regions, where first responders often rely on basic medical supplies and minimal medical training to stop potentially fatal bleeding (Henry & Reingold, 2012; World Health Organization, 2005). These similar boundaries also occur in Palestine, the West Bank, where delays at checkpoints and other limitations further complicate the situation (World Health Organization, 2024).

Current bleeding control methods have significant limitations (Chang et al., 2022; Rittblat et al., 2024). Tourniquets can effectively stop bleeding within a short period of time, but they can cause nerve or tissue damage, or even the possibility of the loss of limb function if applied for extended periods of time (Chang et al., 2022; Sabaté-Ferris et al., 2022; Rittblat et al., 2024). Tourniquets can be even more problematic in low-resource and conflict settings, where the time for evacuation is unknown, and moving from one point to another is potentially dangerous (Henry & Reingold, 2012; World Health Organization, 2005). These circumstances may require the use of a tourniquet for an extended period of time (Henry & Reingold, 2012). In this case, prolonged tourniquet application may increase the risk of complications (Chang et al., 2022; Rittblat et al., 2024). On the other hand, improvised direct pressure using hand, cloth, or bandages can fail to deliver sufficient and constant pressure, especially for deep wounds (Milic et al., 2010; Mumtaz et al., 2023). These limitations highlight the potential value of exploring low-cost, reusable methods that can deliver localized, adjustable pressure to the injury site without total limb compression.

This study investigates this concept by evaluating a low-cost, manual, adjustable pressure device that is designed to apply localized pressure to the wound site. The device is made of a small inflatable air bladder with hemostatic pads to help stop bleeding while avoiding complete occlusion of flow. To evaluate the device, a survey and experimental bench-testing approach was used. This study aims to serve as an early-stage proof of concept and to assess the feasibility of the device and its potential as a bleeding-control solution for low-resource and emergency settings.

METHODS

This research consisted of two components. The first component was an online survey conducted to investigate the participants' knowledge, awareness, and acceptance of current bleeding-control methods and the proposed device. The second component was laboratory testing on a manually adjustable pressure device using a gelatin-based arm model to assess its performance compared to traditional methods–tourniquets and applied pressure. These components separately assessed participant acceptance of the proposed concept and the prototype's preliminary bench-top performance.

3.1 Study design: The study was conducted using a survey and experimental bench-testing design utilizing an online survey with 200 participants to gather participants' knowledge and perceptions of existing bleeding-control methods and their perceived need for and acceptance of the proposed pressure-device concept. Laboratory testing of a manually adjustable pressure device on a gelatin arm model was conducted to evaluate the device's performance compared to traditional tourniquets and applied pressure using cloth or bandages. All testing and data gathering were done in a controlled setting in Palestine, West Bank, during December 2025.

3.2 Survey Methods: A total of two hundred participants completed the online survey over a two-week period. Recruitment was done through WhatsApp groups, different social media platforms, and in-person sharing in clinics, hospitals, and medical centers. Participants included individuals with previous medical or first-aid experience, and all of them were required to be eighteen years of age or older and able to fill out the survey electronically.

Because recruitment included social media platforms and healthcare settings and a high proportion of respondents reported previous medical or first-aid training, the survey sample should not be considered representative of the general population.

3.2.1 Survey Instrument: The online survey consisted of ten multiple-choice and Likert-scale questions covering:

- Prior training or experience in first aid or bleeding control.
- Confidence in dealing with a severe bleeding event.
- Familiarity with tourniquets.
- Acceptance of the proposed manual pressure device concept.
- Safety concerns associated with current bleeding-control methods.
- Age of participant.

The full wording of the closed-ended survey questions, response options, and distribution of participant responses are reported in Table 1.

No identifying information was collected from participants, and participation was completely anonymous and voluntary.

3.2.2 Ethical Considerations: The survey was voluntary, and participants stayed anonymous. It was classified as minimal risk. The study obtained an ethical review and approval through a school-based ethics evaluation process that also included revision by a licensed psychologist before data collection. All participants provided consent before filling out the survey. Prototype testing was conducted on a gelatin model arm. No testing was done on actual humans.

3.3 Prototype Construction: The prototype included a manual inflation bulb, an inflatable air bladder, a pressure gauge, a safety valve, and hemostatic bandages stitched to the inner surface of the inflatable air

bladder. The prototype used a large adult adjustable cuff for limb circumferences of 25 to 42 cm. The cuff was connected via flexible pneumatic tubing to a manual inflation bulb and an analog pressure gauge with a measurement scale up to 300 mmHg. The cuff was placed over the model and fastened with the overlapping closure system. Therefore, bandages would have direct contact with the wound site and provide localized compression. The amount of pressure applied on the gelatin arm was recorded with the help of an HX710B pressure sensor. Before the experimental testing, the HX710B pressure sensor was calibrated with an independent reference pressure measuring device. Before prototype testing, the sensor readings were checked by taking measurements at various applied pressure levels throughout the testing range. The pressure sensor was embedded in the gelatin arm and measured the pressure applied from all three bleeding-control methods during testing. The pump was controlled using an Arduino Uno, allowing changes in flow rate over time rather than constant fluid output.

Simulated blood was circulated using a 12 V DC diaphragm pump with a manufacturer-rated flow of approximately 1.5–2.0 L/min. The inner diameter of the pump outlet was 6 mm and the outer diameter was 8.5 mm. Instead of a constant maximum output from the pump, we used an Arduino Uno to control the output of the pump (i.e. change the flow variation in relation to time). The actual baseline flow rate and internal fluid pressure in individual trials were not measured directly. The HX710B pressure sensor was used only to measure the external pressure applied to the gelatin arm by each of the three bleeding-control methods.

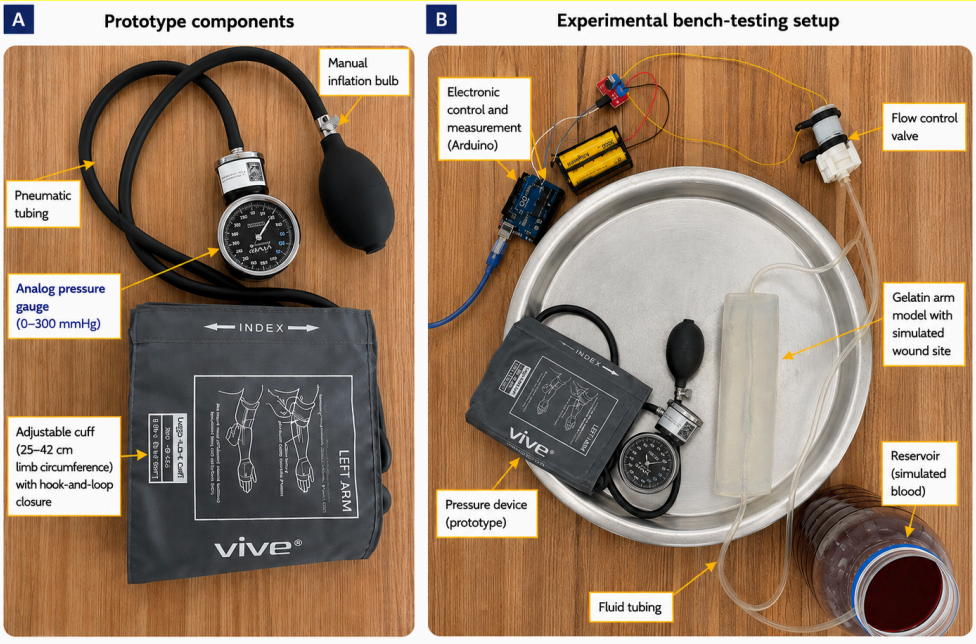


Figure 2. Physical prototype components and experimental bench-testing setup. (A) The manual adjustable pressure device components, including the adjustable cuff, manual inflation bulb, analog pressure gauge (0–300 mmHg), and pneumatic tubing. (B) The experimental bench-testing setup showing the gelatin-based arm model with simulated wound, fluid-flow system with reservoir, flow control valve, pressure device, and electronic measurement equipment.

Prototyping was done using three bleeding-control methods under identical simulated wound conditions. First: a standard tourniquet, second: direct pressure using a cloth bandage, third: the manual, adjustable pressure device. All methods were tested on similar gelatin arm models using the same pump setup and testing procedure to generate simulated blood flow through the wound site to ensure direct and reliable comparisons between the three methods.

The manual inflation bulb was used to inflate the air bladder, while the safety valve allowed the applied pressure to be adjusted or released as needed adaptively depending on the severity of the wound and aspects of the accident setting. Rather than being designed to completely occlude flow through the model, the bladder was used to apply localized pressure directly to the simulated wound. Although the local pressure technique maintains enough pressure to reduce the wound bleeding, it also aims to avoid the complete occlusion of simulated flow through the model. The pressure gauge worked as the feedback mechanism. The user could continuously monitor applied pressure from the cuff and adjust the pressure until the predefined bleeding-control endpoint was reached. The overall design of the device allows it to function without electrical components, making it easier, faster to use, and more suitable for field use, especially in low-resource and emergency settings.

3.3.1 Gelatin limb model: A gelatin arm model was used for testing. This model was chosen for its safety and low cost. The model was created by mixing 10 grams of gelatin with 990 grams of water, then heating the mixture to a boiling temperature, and finally pouring the heated mixture into a cylindrical container. After the model solidified, a wound opening of about 5 cm in length was created on the surface of the gelatin model. The gelatin model was used to simulate a blood vessel by inserting transparent polyurethane (PU) tubing with an outer diameter of 6 mm and an inner diameter of 4 mm. The tubing was connected to the 12 V DC diaphragm pump using a connector. An approximately 3.5 cm long incision was made in the tubing at the simulated wound site, allowing the artificial blood to flow through the wound opening. The models allowed testing multiple times under identical conditions and helped compare different bleeding control methods without involving human participants.

3.3.2 Simulated Blood Preparation: Artificial blood was made to allow safe and reliable assessments of bleeding control methods during testing. The simulated blood consisted of warm water mixed with food coloring and corn syrup to approximate blood viscosity, color, and flow behavior (Lim et al., 2016), while remaining non-toxic and user-friendly with the tubing system. For each test, 1.5 liters of blood was prepared, ensuring sufficient blood flow throughout the whole test period. The use of simulated blood during testing ensured no biologically related risks and supported comparison between different bleeding-control methods.

3.4 Prototype Testing Procedure: Three bleeding control methods were analyzed in this study, all under identical laboratory conditions: a standard tourniquet, direct pressure using a cloth bandage, and the

manually adjustable pressure device. For each test, simulated continuous bleeding was created through the tubing that was embedded in the gelatin arm. About 5 seconds after the bleeding started, one of the three bleeding-control methods was applied using standard use principles. For the tourniquet trials, the tourniquet was positioned approximately 6 cm proximal to the simulated wound and tightened around the gelatin arm using its strap mechanism until the predefined bleeding-control endpoint was reached. For the cloth/bandage trials, the bandage was placed directly over the simulated wound and manual pressure was applied over the wound site until the predefined bleeding-control endpoint was reached. For the manual adjustable pressure device trials, the cuff was applied around the gelatin arm with the hemostatic bandage directly over the simulated wound. The inflation bulb was squeezed manually to raise the pressure in the air bladder until the predefined bleeding-control endpoint was reached, while the pressure gauge was used to monitor the applied pressure. Similar gelatin arms, bleeding conditions, and testing procedures were used in all the tests to ensure precise results. During and after testing, multiple metrics were recorded, including: initial bleeding rate, time to stop visible bleeding, total fluid lost before bleeding control, final pressure applied, pressure stability over the first 60 seconds, observed effect on gelatin model, and ease of application. This standardized setup allowed direct comparison among the bleeding-control methods without involving human participants.

For the purpose of prototype testing, bleeding control was operationally defined as the point at which there was no longer continuous visible flow of simulated blood from the wound and only minimal residual leakage remained. The model was perfused with continuous flow of artificial blood and did not reproduce physiological clotting, therefore complete biological hemostasis could not be evaluated.

The simulated circulation was judged visually by seeing whether artificial blood continued to flow through the tubing beyond the site of application of each bleeding-control method. Complete occlusion of simulated flow was defined as no visible flow through the tubing distal to the compression site, whereas maintained simulated flow was defined as continued visible flow beyond the compression site. This evaluation was qualitative, not quantified with a separate flow sensor.

Each method was tested three times, resulting in nine experimental trials in total. Three gelatin arm models were used, with one model assigned to each bleeding-control method. The same model dimensions, simulated wound characteristics, tubing setup, simulated blood preparation, and testing procedure were maintained across the three methods. The values reported in the results section were found by calculating the mean of the values of the three trials for each method. Repeated use of the gelatin arm model for each of the three methods may have affected the characteristics of the model and therefore should be acknowledged as a limitation of the prototype testing procedure.

3.5 Data Analysis: Data were exported from the online survey platform and then analyzed using frequencies and percentages to summarize participants' prior training or experience in first-aid or

bleeding-control, confidence in dealing with a severe bleeding event, familiarity with different bleeding-control methods, acceptance of the proposed manual pressure device concept, and safety concerns associated with current bleeding-control methods. No inferential statistical tests were performed, since this study is experimental. The survey was distributed through social media platforms such as WhatsApp groups and remained open for two weeks before responses were exported and analyzed.

Data from prototype testing were gathered during and after each experiment. The results recorded included the initial bleeding rate, time to visible bleeding control, total simulated fluid loss before bleeding control, final applied pressure, pressure stability over the first 60 seconds, observed effects on the gelatin model, and ease of application. For each method, the results of the three trials were summarized with mean and standard deviation to describe the between-trial variability.

3.6 Ethical Considerations / Ethical Approval: The study only involved voluntary and anonymous participation and was classified by reviewers as minimal risk. No classified or sensitive personal information was gathered from the participants. All participants were informed of the purpose of the online survey and provided electronic consent before completing the survey. Ethical approval was obtained through a detailed school-based ethics review process, in which the paper was reviewed by a school teacher, the school's administrator, and a certified psychologist prior to data collection. In addition to the school-based review, ethical approval was also obtained by Horizons Academy in Palestine. Survey responses were stored electronically on the secure online survey platform, and participation was completely voluntary; all participants were free to withdraw their answers at any time. Prototyping was done in a controlled setting and was done on a gelatin arm model with no human participation.

RESULTS

4.1 Survey Results: A total of 200 participants filled out the survey, all of whom were 18 years of age or older. Of the 200 participants, 87.5% reported previous medical or first-aid training, indicating that the survey sample had substantial prior exposure to these topics. The majority of the respondents had basic knowledge about existing bleeding-control methods, with 64% reporting knowledge about how to use or having previously used a tourniquet, while 44.5% said they would apply pressure with cloth or bandages in case of a bleeding emergency. About half the participants felt "very confident" in their ability to handle a major bleed in an emergency situation, while others reported only moderate or limited confidence.

Table (1): Survey questions and distribution of participant responses (n = 200)

Survey question	Response option	n	%
1. How old are you?	18 years or older	200	100.0
2. Have you ever received any kind of training in first aid or bleeding control?	Yes	175	87.5
	No	25	12.5
3. If you witnessed a severe bleed, which method would you most likely use?	Apply pressure with a cloth or bandage	89	44.5
	Use a tourniquet	72	36.0
	Call for help only	28	14.0
	I'm not sure	11	5.5
4. Have you heard about or used a tourniquet before?	Yes, used it	128	64.0
	Heard of it but never used	53	26.5
	No, never heard of it	19	9.5
5. How confident do you feel in your ability to stop bleeding in an emergency?	Very confident	100	50.0

	Somewhat confident	67	33.5
	Not confident	33	16.5
6. Tourniquets can sometimes cause pain or tissue damage. Would you support a new device that applies controlled pressure without stopping full blood flow?	Yes	184	92.0
	Maybe	14	7.0
	No	2	1.0
7. Do you think tourniquets are always safe to use?	No	149	74.5
	Yes	33	16.5
	Not sure	18	9.0
8. What do you think is most important in a bleeding control device?	Fast bleeding control	89	44.5*
	Safety and comfort	75	37.5*
	Ease of use	35	17.5*
	Low cost	20	10.0*
	Reusability	20	10.0*

*For Question 8, some respondents selected more than one response option despite the question instructing participants to select one; therefore, response percentages for this item are not mutually exclusive and may sum to more than 100%. Optional open-ended responses were not included because no formal qualitative analysis was performed.

Concerns regarding tourniquet safety were common: 74.5% of participants reported that tourniquets are not always safe to use, while 16.5% considered them consistently safe. When the participants were introduced to the concept of a manual, adjustable pressure device that applies direct pressure to the wound site, while avoiding complete circulation cutoff, about 92% believed such a device is needed, and 74%

stated it would “help a lot” in real emergencies. In addition, 84% rated improving bleeding-control devices for emergencies as ‘very important.’

4.2 Prototype Testing Results: Prototype testing compared the tourniquet, cloth/bandage, and manual adjustable pressure device under standardized simulated wound conditions. First: a standard tourniquet, second: direct pressure using a cloth bandage, third: the manual, adjustable pressure device. All methods were tested on similar gelatin arm models using the same pump setup and testing procedure to generate simulated blood flow through the wound site to guarantee direct and reliable comparisons between the three methods.

Of the three methods, the tourniquet was able to stop the bleeding the fastest, having done so in approximately 6 seconds. The total volume of simulated blood lost while testing prior to bleeding control was about 20 mL. However, the tourniquet applied the highest mean pressure amounts on the gelatin arm model, having applied a mean pressure of 221 ± 3 mmHg to the gelatin arm model, and resulted in the process in complete occlusion of simulated flow through the tubing distal to the compression site. Following testing, marked compression and extreme deformation of the gelatin arm were observed.

On the other hand, improvised direct pressure from the cloth bandage took the longest time of all the methods to stop the bleeding, having achieved complete bleeding control in approximately 45 seconds. The total volume of blood loss prior to complete bleeding control was higher, totaling 68 mL. The cloth/bandage method applied a mean pressure of 46 ± 9 mmHg during testing and led in the process to circulation being partially maintained through the tubing, based on visual observation. After testing, uneven deformations were observed on the gelatin arm.

Lastly, the manual, adjustable pressure device achieved bleeding control within approximately 14 seconds and resulted in 28 mL of simulated blood loss. The device applied a mean pressure of 134 ± 12 mmHg and remained stable over a 60-second period, with less than a 5% decrease observed. In the testing process, simulated flow remained visible through the tubing distal to the compression site. After testing, only localized slight deformation on the wound site was observed.

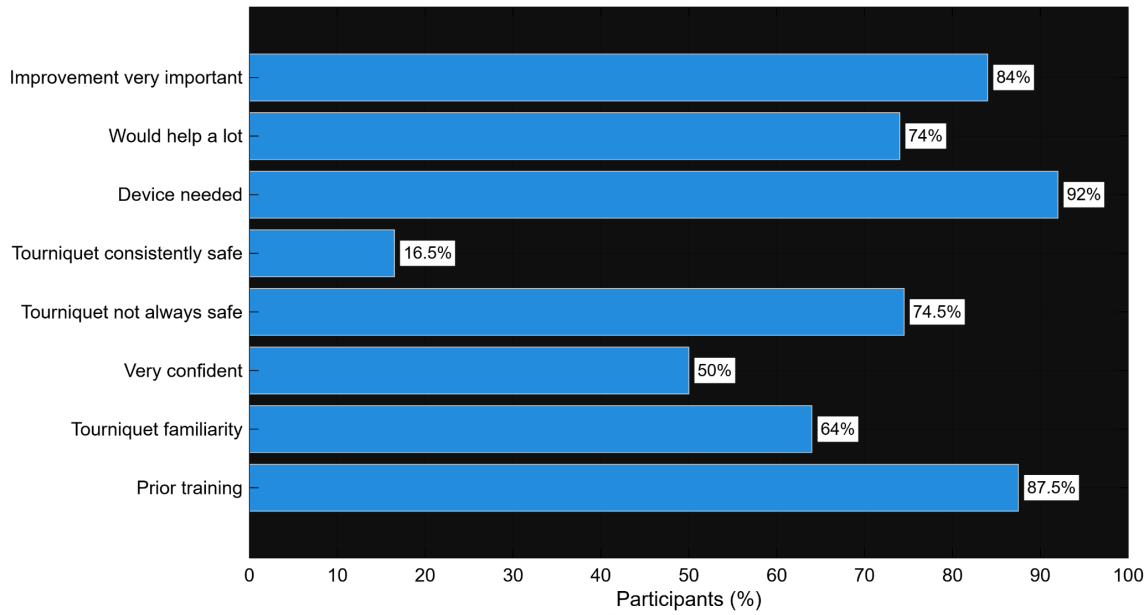
Across the three methods tested, clear differences were observed in time to complete bleeding control, pressure applied to the gelatin arm, effect on simulated blood circulation, and finally observed deformation on the gelatin arm. The tourniquet and manual, adjustable pressure device achieved faster bleeding control compared to improvised bandage pressure. The manual, adjustable device did not completely occlude simulated flow through the tubing under the tested conditions, while localized deformation was observed at the simulated wound site. All the results were documented and then

summarized in tables to allow direct comparison of bleeding-control performance of the methods under identical simulated conditions.

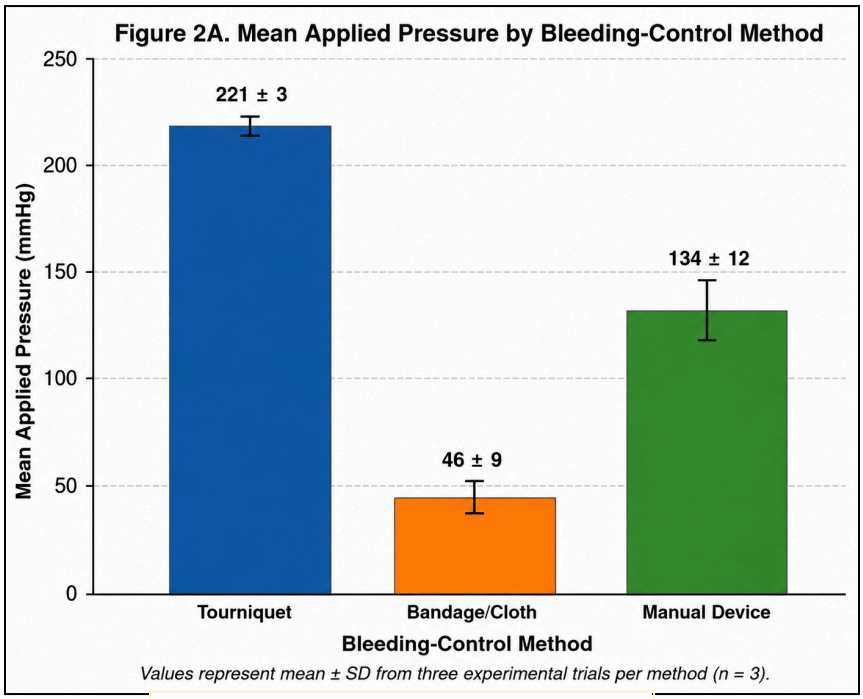
Measurement	Method	Trial 1	Trial 2	Trial 3	Mean ± SD
Time to bleeding control (s)	Tourniquet	5	7	6	**6.0 ± 1.00**
	Bandage/Cloth	47	42	46	**45.0 ± 2.65**
	Manual device	13	16	13	**14.0 ± 1.73**
Simulated blood loss (mL)	Tourniquet	18	22	20	**20.0 ± 2.00**
	Bandage/Cloth	71	64	69	**68.0 ± 3.61**
	Manual device	30	25	29	**28.0 ± 2.65**
Applied pressure (mmHg)	Tourniquet	218	224	221	**221.0 ± 3.00**
	Bandage/Cloth	55	37	46	**46.0 ± 9.00**
	Manual device	122	146	134	**134.0 ± 12.00**

Table (2): Prototype Testing Results Across Three Experimental Trials

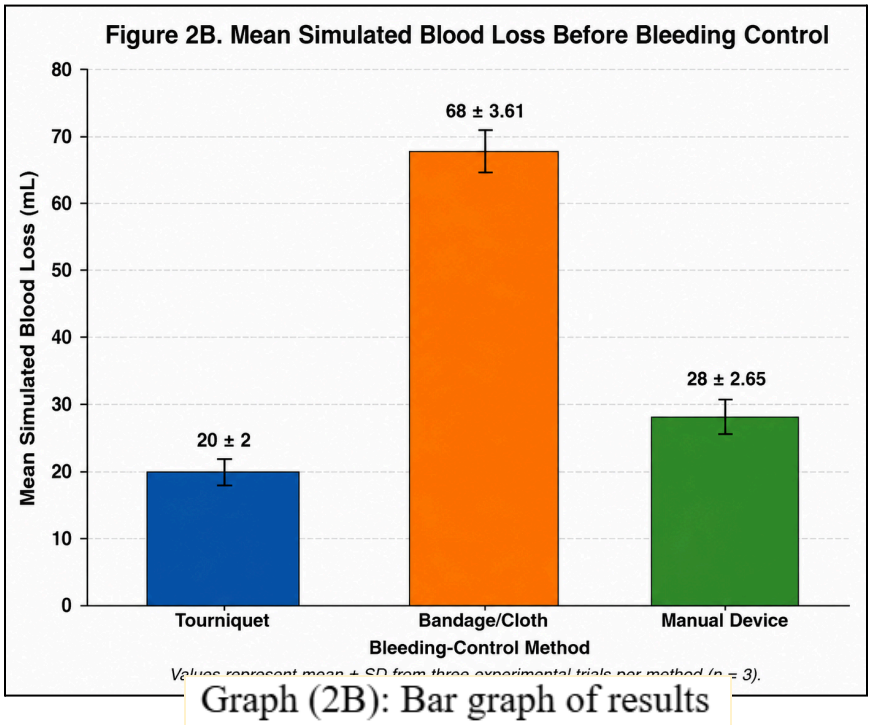
Values represent individual experimental trials. Mean values and standard deviations (SD) were calculated from three trials per bleeding-control method (n = 3).



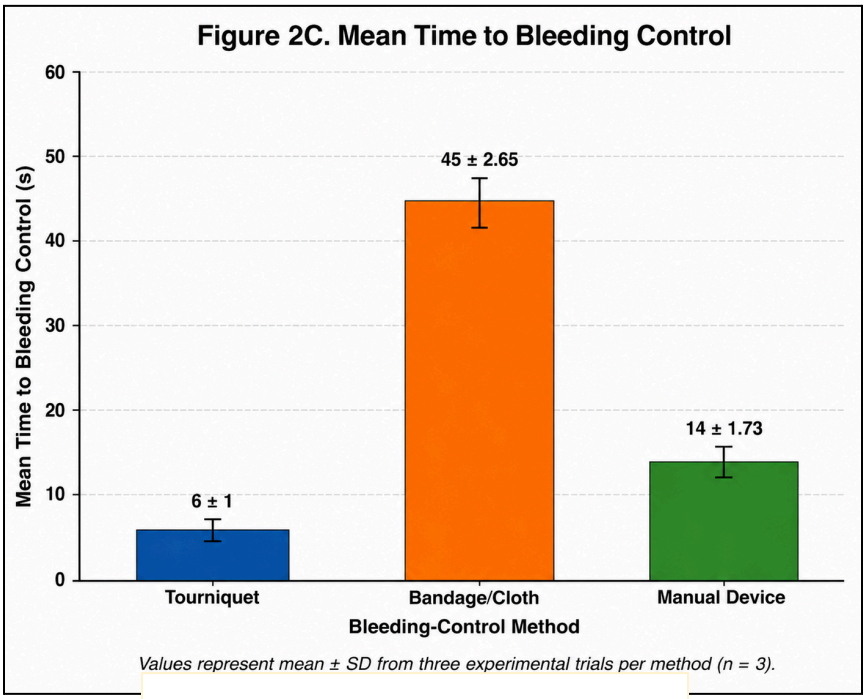
Graph (1): Visible survey results



Graph (2A): Bar graph of results



Graph (2B): Bar graph of results



Graph (2C): Bar graph of results

4.3 Results Summary: Survey findings indicated that most participants were aware of available bleeding control methods and that concerns regarding tourniquet safety were widespread. A large proportion of participants also showed high acceptance of the proposed manual adjustable pressure-device concept. In separate laboratory testing, the three methods differed in time to bleeding control, applied pressure, simulated blood loss, simulated flow, and deformation of the gelatin model.

DISCUSSION

5.1 Principal Findings: The study combined an online survey and experimental bench testing to explore the practicality of a manual, adjustable pressure-based device for bleeding control, especially in low-resource and conflict settings. Survey findings showed that a high proportion of participants were familiar with existing bleeding-control methods, while concerns regarding tourniquet safety were common. Despite the high proportion of participants with prior first-aid or bleeding-control training, only half reported feeling 'very confident' in their ability to stop bleeding in an emergency, while 33.5% were 'somewhat confident' and 16.5% were 'not confident' in managing bleeding in an emergency setting, highlighting the challenges of effective bleeding control in real-world scenarios (World Health Organization, 2005; Henry & Reingold, 2012). On the other hand, acceptance of the proposed pressure-device concept was also high, with most respondents expressing support for a device designed to apply controlled pressure without completely stopping simulated flow. These survey findings reflect participants' perceptions and acceptance of the proposed device concept and should be interpreted separately from the prototype's bench-testing results.

Separately, prototype testing provided preliminary mechanical data on the performance of the three bleeding-control methods under controlled gelatin-model conditions. Although all three methods were able to achieve bleeding control under identical conditions, clear differences were observed in time to complete bleeding control, pressure applied to the gelatin arm, effect on simulated blood circulation, and finally observed deformation on the gelatin arm. The tourniquet was able to achieve bleeding control the fastest, with the lowest amount of fluid loss. However, the extremely high pressure applied caused complete occlusion, and following testing, extreme deformation was found on the gelatin arm (Chang et al., 2022; Xacur-Trabucleo et al., 2025). The bandage method was much slower, inconsistent, and allowed substantial fluid loss due to unstable pressure applied. In contrast, the manual, adjustable pressure device was able to stop bleeding in less time than the bandage method under the tested conditions, while maintaining localized, stable pressure and preserving simulated circulation. Together, all of these findings strongly support the crucial need for future research and development in the field of bleeding-control management, in order to find safer, more reliable, and easier-to-use methods and to investigate how new approaches may complement established bleeding-control methods such as tourniquets and direct pressure.

5.2 Interpretation in the Context of Existing Literature: The findings of this study are generally consistent with existing research on the benefits and risks of different bleeding control methods, such as tourniquets (Chang et al., 2022; Xacur-Trabucleo et al., 2025). Tourniquets are very effective in bleeding control and can achieve rapid bleeding control, but there are a number of clinical reports and past papers that document the risks of tourniquets (Kauvar et al., 2006; Chang et al., 2022), especially when applied for extensive periods of time, including severe nerve and tissue damage, and even the possibility of complete loss of limb function (Chang et al., 2022; Rittblat et al., 2024; Xacur-Trabucleo et al., 2025). These risks are particularly relevant in low-resource and conflict settings where access to advanced medical care and transport is very limited (Henry & Reingold, 2012; World Health Organization, 2005).

Improvised applied pressure using bandages or clothes is recommended as a first response in bleeding scenarios, yet prior research shows that pressure applied this way is inconsistent and hard to maintain for long periods of time (Milic et al., 2010; Mumtaz et al., 2023). Stress, fatigue, and other conditions can easily affect the amount of pressure applied to the wound, which in most cases won't match arterial pressure, limiting the effectiveness of this method in achieving bleeding control (Milic et al., 2010; Mumtaz et al., 2023). These challenges regarding improvised pressure align with the results of this study.

Previous studies on compression bandages and hemostatic material indicate that bleeding control is achieved more effectively if constant pressure is applied directly to the wound site, rather than suppressing the whole limb (Milic et al., 2010; Mumtaz et al., 2023). Further research into bandage pressure also indicates that the application of pressure within a specific range without inhibiting blood flow can help in limiting complications (Sabaté-Ferris et al., 2022; Xacur-Trabucleo et al., 2025). The design rationale for the manually adjustable pressure device follows this approach in that localized pressure is used and does not completely occlude flow simulated through the model.

Overall, the findings are consistent with previous research on localized compression and support further investigation of adjustable-pressure approaches as potential complements to established bleeding-control methods.

5.3 Relevance to Low-Resource and Emergency Settings: The findings of this study are particularly relevant to low-resource settings and in conflict-affected areas, where access to hospitals and immediate healthcare is very limited (Henry & Reingold, 2012; World Health Organization, 2005). In such conditions, civilians with varying levels of first-aid or medical experience may have access only to basic first-aid resources when immediate care is needed. In Palestine, the West Bank, for example, restrictions on movement, lack of medical equipment, delays at checkpoints, and limited access to professional care from medics add to the natural risks of hemorrhages (World Health Organization, 2024). In such environments, bleeding control methods that rely on complete limb occlusion, such as tourniquets, pose a lot of additional risks if evacuation is delayed (Chang et al., 2022; Rittblat et al., 2024). Similarly, improvised pressure using clothes or bandages may be very difficult to maintain for long periods of time,

particularly in high-stress situations (Milic et al., 2010; Mumtaz et al., 2023). Emergency care in low-resource settings often depends on tools that are easy to use and reliable over extended periods (Henry & Reingold, 2012). While further testing is required, these features may be relevant for bleeding control in conflict-affected environments.

5.4 Strengths and Limitations: This study has several strengths. The study incorporated an online survey and experimental bench testing to assess the preliminary feasibility of a manual device with adjustable pressure in controlling bleeding, especially in resource-constrained and war-torn environments. All the bleeding control techniques were subject to the same test conditions using similar gelatin limb models with simulated bleeding. The use of a simulated gelatin arm model allowed repeated, safe, and ethical testing without involving human or animal subjects (Jandial et al., 2008). In addition, this pressure-based, non-electric device could address commonly encountered challenges in low-resource and emergency settings (Henry & Reingold, 2012; World Health Organization, 2005).

On the other hand, this study has several important limitations. First, prototype testing was conducted using a gelatin-based limb model, which does not fully replicate the complexity of the human body's limbs. The model cannot simulate clotting factors, tissue flexibility, or physiological responses to trauma. Specifically, vascular compliance, tissue elasticity, coagulation, differences among vessel types, and physiological responses to compression are not modeled. Thus, the reported pressure, simulated flow, blood loss, and bleeding-control results should be understood as bench-top mechanical observations, rather than as direct representations of human physiologic reactions.

Second, it was conducted in a controlled environment. In a real-world scenario, emergencies are full of moving patients, poor vision, stress, panic, and uneven wounds. All these were not considered in this current study. Lastly, this study is considered a preliminary study, and it is considered a proof of concept. There were no tests done on humans or animals; thus, it should not be considered evidence of clinical effectiveness or safety because it should be subjected to more tests on different models.

Third, the survey also has important limitations. Participants were recruited through social media platforms and healthcare settings, and 87.5% reported previous medical or first-aid training; therefore, the sample may not be representative of the general population and may be subject to selection bias. In addition, participants were introduced to the proposed device as a concept that could maintain circulation while controlling bleeding before being asked about its perceived need and usefulness. This wording may have influenced responses toward greater acceptance of the device, introducing potential response bias. Therefore, the survey findings should be interpreted as measures of participants' perceived need and acceptance of the proposed concept rather than evidence of clinical need or effectiveness.

5.5 Acknowledgements: The author is grateful for the support, resources, and guidance received from Dr. Issac Gill, without whom this paper would not have been possible. The author would also like to acknowledge the publishing support and resources received from the Lumiere Program.

CONCLUSION

This study evaluates a manual, adjustable pressure device that is designed for low-resource and emergency settings. Uncontrolled bleeding remains one of the leading causes of preventable deaths in the world, especially in low-resource and emergency settings, where access to hospitals and immediate healthcare is very limited. The study consists of an online survey with 200 participants and laboratory testing of a manual adjustable pressure device on a gelatin arm model. The goal of using this design was to gather public knowledge and opinions on existing methods and the potential of supporting a new pressure-device concept, while also evaluating the device's performance compared to traditional tourniquets and applied bandage pressure.

The survey results showed that most participants were familiar with existing bleeding-control methods and safety concerns; especially those related to tourniquets were very common. By contrast, a high proportion of participants reported acceptance of a new manual, adjustable pressure-based bleeding control device. On the other hand, in laboratory testing, clear differences were observed in time to complete bleeding control, pressure applied to the gelatin arm, effect on simulated blood circulation, and observed deformation on the gelatin arm. All the prototyping results were documented and then summarized in tables to allow direct comparison of different bleeding-control methods. The survey indicated high acceptance of the proposed device concept and the prototype testing provided preliminary evidence of its benchtop feasibility under the tested conditions.

This study indicates promising preliminary benchtop feasibility of a manual, adjustable pressure device for bleeding control, especially in low-resource and emergency environments. Further testing on advanced models is recommended before drawing final conclusions regarding clinical safety, effectiveness, or the device's potential role relative to established bleeding-control methods.

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