ORIGINAL RESEARCH

Aquatic Feasibility of Limbs Application of Tourniquets (AFLAT) during a Lifeguard Water Rescue: A Simulation Pilot Study

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Abstract

Introduction: Control of massive hemorrhage (MH) is a life-saving intervention. The use of tourniquets has been studied in prehospital and battlefield settings but not in aquatic environments.

Objective: The aim of this research is to assess the control of MH in an aquatic environment by analyzing the usability of two tourniquet models with different adjustment mechanisms: windlass rod versus ratchet.

Methodology: A pilot simulation study was conducted using a randomized crossover design to assess the control of MH resulting from an upper extremity arterial perforation in an aquatic setting. A sample of 24 trained lifeguards performed two randomized tests: one using a windlass-based Combat Application Tourniquet 7 Gen (T-CAT) and the other using a ratchet-based OMNA Marine Tourniquet (T-OMNA) specifically designed for aquatic use on a training arm for hemorrhage control. The tests were conducted after swimming an approximate distance of 100 meters and the tourniquets were applied while in the water. The following parameters were recorded: time of rescue (rescue phases and tourniquet application), perceived fatigue, and technical actions related to tourniquet skills.

Results: With the T-OMNA, 46% of the lifeguards successfully stopped the MH compared to 21% with the T-CAT ($P = .015$). The approach swim time was 135 seconds with the T-OMNA and 131 seconds with the T-CAT ($P = .42$). The total time (swim time plus tourniquet placement) was 174 seconds with the T-OMNA and 177 seconds with the T-CAT ($P = .55$). The adjustment time (from securing the Velcro to completing the manipulation of the windlass or ratchet) for the T-OMNA was faster than with the T-CAT (six seconds versus 19 seconds; $P < .001$; effect size [ES] = 0.83). The perceived fatigue was high, with a score of seven out of ten in both tests ($P = .46$).

Conclusions: Lifeguards in this study demonstrated the ability to use both tourniquets during aquatic rescues under conditions of fatigue. The tourniquet with the ratcheting-fixation system controlled hemorrhage in less time than the windlass rod-based tourniquet, although achieving complete bleeding control had a low success rate.

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Introduction

Keywords: bleeding; drowning; lifeguards; simulation; tourniquet

Abbreviations:
ES: effect size
MH: massive hemorrhage
RPE: rating of perceived effort
T-CAT: Combat Application Tourniquet 7 Gen
T-OMNA: OMNA Marine Tourniquet

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Massive hemorrhage (MH) is a time-dependent emergency that can occur in an aquatic environment.[1] Recreational activities involving boats, water sports, aquatic sliding sports such as surfing or kitesurfing,[2] or attacks from marine animals like sharks or alligators[3] can potentially trigger a MH, posing an immediate life-threatening risk.[4] One of the fastest and most effective interventions for controlling this emergency is the use of a tourniquet,[5,6] provided that proper application is feasible. Lifeguards are the professionals responsible for prevention, rescue, and mitigation in aquatic settings;[7] however, the use of tourniquets in aquatic incidents currently represents a knowledge gap. The reality is that a standard water rescue will take several minutes to reach land, regardless of the equipment – fins, rescue tube, or rescue water craft – used by lifeguards.[8] During aquatic transportation in the event of MH, this time is extremely critical and potentially fatal. Therefore, an alternative for survival could be the application of the tourniquet in the water while in contact with the victim.

Currently, there are numerous tourniquets available on the market, manufactured with different materials and adjustment mechanisms. Perhaps the most well-known and widely used tourniquet in tactical medicine is the Combat Application Tourniquet 7 Gen (T-CAT; North American Rescue; Greer, South Carolina USA).[9] Its mechanism for controlling MH is based on a windlass rod system. However, the industry has evolved towards more specific designs, recently introducing an aquatic tourniquet model with strap adjustment and ratchet pull. The aim of this research is to evaluate MH control in the aquatic environment by analyzing the usability of two tourniquet models with different types of adjustment mechanisms: windlass rod versus ratchet.

Method

Design

A pilot study, randomized and crossover in design, was conducted to assess the control of a MH in the right upper limb following a simulated aquatic rescue. Two types of tourniquets were compared: (1) T-CAT 7 Gen model, which utilizes windlass rod adjustment and is recommended for general rescue but not for aquatic environments; versus (2) OMNA Marine Tourniquet (OMNA Inc.; Saint Petersburg, Florida USA)[10] featuring ratchet adjustment and recommended for use in aquatic environments (T-OMNA; Figure 1). The study was approved by the Ethics Committee of the Faculty of Education and Sports Sciences (University of Vigo; Pontevedra, Spain) with code 19-0721. Prior to the study, informed consent was obtained from all participants.

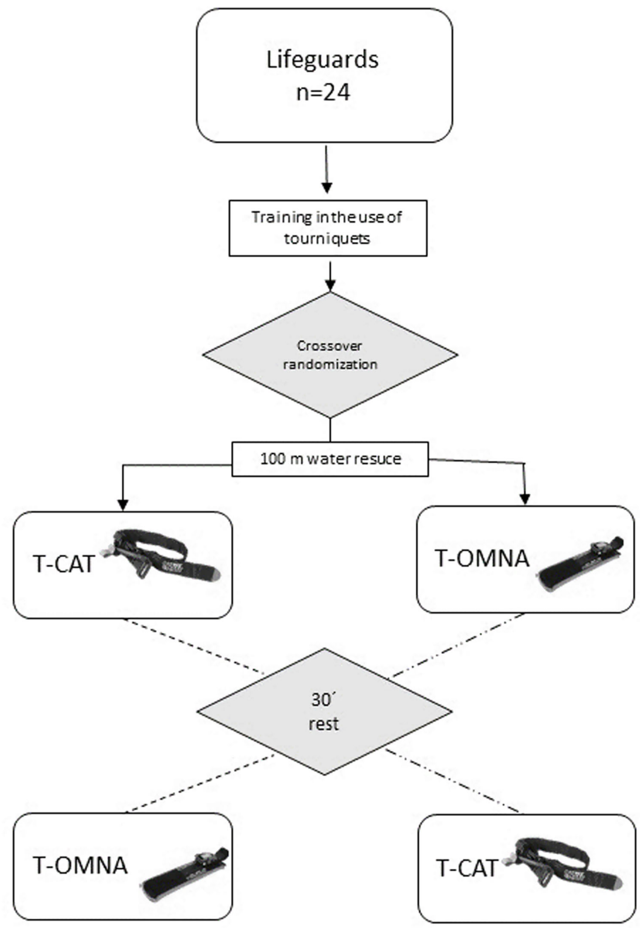

Figure 1. Study Design.
Abbreviations: T-CAT; Combat Application Tourniquet 7 Gen; T-OMNA, OMNA Marine Tourniquet.

Selection of Participants

The inclusion criteria required participants to be trained lifeguards with experience in rescues in natural aquatic spaces and knowledge of how to handle a MH.

Practical Training

Prior to the start of the tests, all participants received a brief theoretical and practical training of 30 minutes on MH and the skills to use a T-CAT following the guidelines of Tactical Combat Casualty Care (TCCC).[11] They also received training on the use of the T-OMNA according to the manufacturer's specifications (Figure 2).[12] This training was conducted by an instructor with experience in using tourniquets in emergencies.

Simulated Scenario

The prehospital scenario consisted of a MH caused by a perforation in the upper limb, specifically on the brachial artery. The simulation was conducted using a hemorrhage control training arm, Model P102 (3B Scientific; Paterna, Spain). The clinical case presented to the lifeguards was as follows:

> A swimmer is struck by a spearfishing harpoon 100 meters from the shore, which, upon removal in situ, causes significant bleeding in the right arm visible even in the water. The objective is to swim this distance as quickly as possible and effectively control the hemorrhage in the water before the rescue and transfer to land.

Each lifeguard performed two tests in a randomized manner: a test with the T-CAT versus the T-OMNA. The lifeguard started from the beach wearing a full 3.2-millimeter wetsuit, fins model Avanti Super-Chanel (Mares; Rapallo, Italy), and rescue tube model MARPA (Emergalia; Ourense, Spain) where the tourniquet was fixed. Lifeguards swam to a pontoon located 100 meters away. Upon arrival, a member of the research team submerged the trauma arm in the water up to shoulder height, and another member of the research team pumped red-tinted liquid to simulate arterial bleeding (Figure 3). The order of the tests was randomized, and

Figure 2. Pre-Training and Types of Tourniquets.
Abbreviations: OMNA, OMNA Marine Tourniquet; CAT 7, Combat Application Tourniquet 7 Gen.

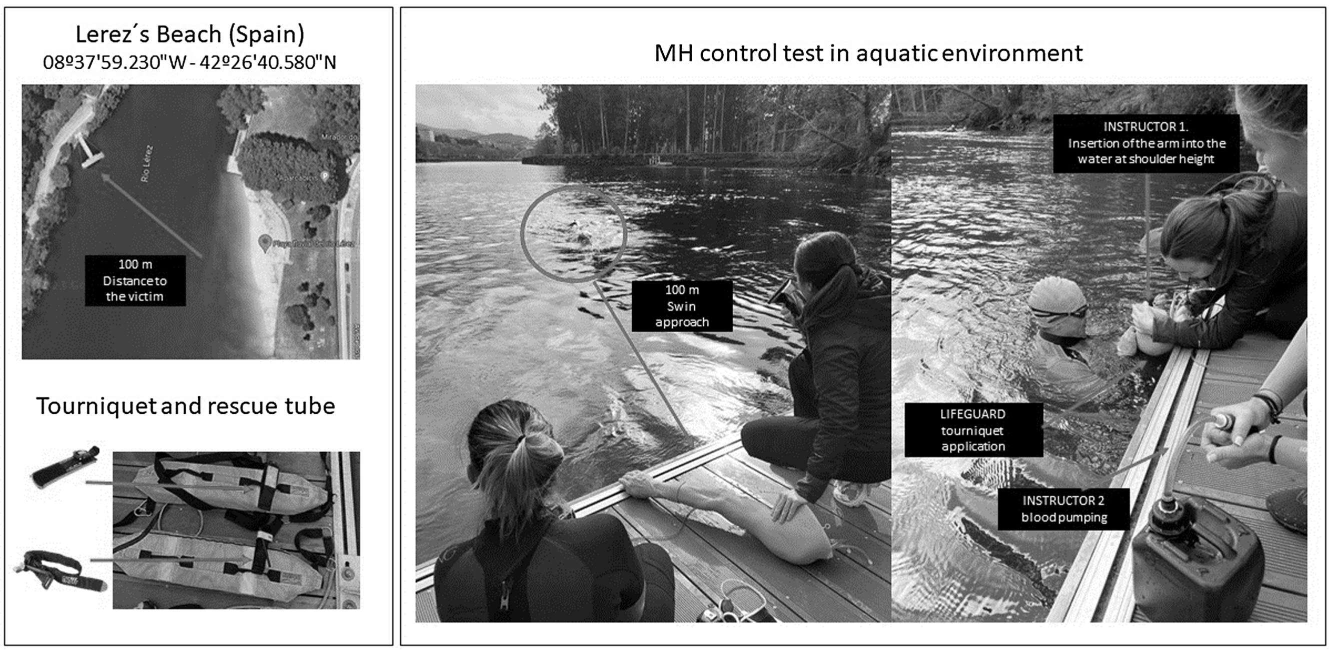

Figure 3. Study Location and Test Procedure.
Abbreviation: MH, massive hemorrhage.

there was a 30-minute rest period between tests to avoid the fatigue effect.

Environmental Characteristics and Weather Conditions

The study was conducted on November 16, 2022 at the river beach of Pontevedra City and the pontoon of the University of Vigo, located on the Lérez River in Pontevedra, Spain. The average ambient temperature during the tests was 11ºC (51.8˚F), and the water temperature was 15ºC (59˚F). It was a generally cloudy day with no wind or other adverse weather conditions.

The depth on the dock was three meters. The lifeguards were not standing and could not hold on to the dock or the mannequin arm; they were kept afloat by the propulsion of their legs. The lifeguards had only one rescue tube and individual goggles.

Variables

Three groups of variables were evaluated: (1) time for the rescue phases, tourniquet application time, and rating of perceived fatigue; (2) skills actions related to tourniquet application; and (3) the quality of tourniquet application steps.

To assess the different tourniquet application steps, direct observation by an instructor and re-verification by another instructor, both with experience in the evaluation of these skills, were used. In addition, the video recording of each test was used. The distance from the wound to the tourniquet was measured at the end of each test using a metric ruler, from the end of the tourniquet strap to the wound site. The evaluation of hemorrhage control was determined by the cessation of bleeding from a puncture wound in the internal arm of the simulated right upper limb.

Time for Rescue Phases, Tourniquet Application Time, and Rating of Perceived Effort (RPE)—Approach rescue time for 100m swim (T1), tourniquet application time in seconds (T2), which was further divided into two phases: the first phase encompassed the time from gripping the tourniquet attached to the rescue tube to passing it around the arm and securing the strap with Velcro (T2.1); and the second phase involved adjusting the tourniquet by rotating the windlass or activating the ratchet (T2.2). Overall time from the start of the test until bleeding cessation (T3). Rating of perceived effort (RPE) was assessed using the modified Foster, et al scale ranging from zero to ten, where zero is no fatigue and ten is extreme fatigue (RPE).[13]

Skills Actions Related to Tourniquet Application—

Phase 1: Tourniquet Adjustment and Positioning
Phase 1 included:

1. Adjusting the tourniquet band to the perimeter of the injured arm (yes/no);
2. Fastening the tourniquet's Velcro (yes/no); and
3. Measuring the distance from the tourniquet to the wound (cm).

Phase 2: Hemorrhage Control
Phase 2 included:

4. Number of windlass rotations/ratchet pulls;
5. Complete cessation of bleeding (yes/no);
6. Secure the T-CAT tourniquet windlass (yes/no);
7. Check for distal pulse (yes/no); and
8. Report the time of tourniquet application (seconds).

Quality of Tourniquet Application Steps—The frequency of performing each step, classified dichotomously (yes/no), by each lifeguard. Percentage of lifeguards who correctly perform all the steps.

Statistical Analysis
All statistical analyses were performed using IBM SPSS for Windows (version 25.0; IBM Corp.; Armonk, New York USA). Continuous variables were described using measures of central tendency (median) and dispersion (IQR: interquartile range). For comparisons of continuous variables, after checking the normality of distributions using the Shapiro-Wilk test, the Wilcoxon signed rank test (non-normal distribution) or Student's t-test (normal distribution) was used. In statistically significant comparisons, effect size (ES) was analyzed using Rosenthal's r test (non-normal distribution) or Cohen's d test (normal distribution). The following classification was used to categorize the ES: <0.2 Trivial; 0.2-0.5 Small; 0.5-0.8 Moderate; 0.8-1.3 Large; and ≥ 1.3 Very Large.

Categorical variables were described using absolute and relative frequencies. The McNemar test was used for comparisons of categorical variables. In statistically significant comparisons, ES was analyzed using Cohen's g test. The following classification was used to categorize the ES: 0.05-0.15 Small; 0.15-0.25 Medium; and ≥ 0.25 Large. A significance level of P = .05 was applied to all analyses.

Results
A sample of 24 lifeguards (75% male and 25% female) participated in this study. The demographic characteristics of the participants were as follows: age 20 (IQR 20-22) years, weight 71 (IQR 63-79) kg, and height 176 (IQR 167-184) cm.

The time taken for the different phases of the rescue and tourniquet application, as well as the perceived fatigue, are presented in Table 1.

The approach swim to the aquatic incident (T1) took just over two minutes, with no significant differences in any of the tests: T-CAT = 131 seconds versus T-OMNA = 135 seconds; P = .42. The tourniquet application time (T2), during the first phase T2.1, also showed no significant differences: T-CAT = 25 seconds versus T-OMNA = 28 seconds; P = .15. However, in the adjustment T2.2, the ratchet tourniquet was significantly faster: T-CAT = 19 seconds versus T-OMNA = six seconds; P < .001 (ES = 0.83).

The analysis of T3 (rescue time + tourniquet application time) showed no significant variation: T-CAT = 177 seconds versus T-OMNA = 174 seconds; P = .55. In both cases (T-CAT and T-OMNA), the rescuers considered the perceived fatigue to be very hard (rating seven out of ten) in both tests; P = .46.

Table 2 shows the skills actions of tourniquet use, disaggregated into two phases. Phase 1 analyzed the band adjustment and the distance of the tourniquet from the wound, where no statistically significant differences were found. More than one-half of the lifeguards achieved a proper band adjustment to the perimeter of the injured arm: T-CAT = 63% versus T-OMNA = 88% (P = .07) and were considered to stick the Velcro properly: T-CAT = 96% versus T-OMNA = 100% (P = 1.00). The distance from the wound to the tourniquet was similar in both cases: four centimeters in both T-CAT and T-OMNA (P = .32).

In Phase 2, which analyzed the tourniquet manipulation to stop the bleeding, there were no statistically significant differences either. The rescuers checked the distal pulse in 63% of T-CAT and 71% of T-OMNA cases (P = .77) and reported the final placement time of the tourniquet to the instructor in 63% of T-CAT tests and 83% with T-OMNA (P = .18).

In Table 3, a summary of each participant's performance in each step of tourniquet application is presented. With the T-OMNA model, 46% of the participants managed to stop the bleeding by performing the band adjustment and Velcro fixation correctly, whereas with the T-CAT model, the percentage was 21%.

Discussion
The objective of the study was to evaluate the ability of rescuers to apply a tourniquet in a simulated aquatic incident and compare two different models: the T-CAT tourniquet, which is the most commonly used, especially in tactical medicine,[9] and a new aquatic model T-OMNA,[10] based on a ratcheting closure. The main findings were as follows:

1. Both models showed similar performance in controlling hemorrhage, although the cessation of bleeding varied from 24% with the T-CAT tourniquet to 46% with the T-OMNA tourniquet.
2. The ratcheting closure system was significantly faster than the model based on a windlass-style stick.
3. Overall, the study indicated that the T-OMNA tourniquet with a ratcheting closure could be a viable alternative to the T-CAT tourniquet in aquatic rescue scenarios, given its faster application time and comparable effectiveness. However, both models showed similar results in stopping bleeding and perceived fatigue among rescuers.

Well-designed tourniquets can reliably control bleeding, mitigate the risk of shock progression, and potentially increase survival rates.[9] However, the conclusive evidence of their benefit in the civilian setting is not clear and may have a multifactorial

		T-CAT		T-OMNA		P Value
T1*		131	(117 - 144)	135	(117 - 155)	P = .42
T2	T2.1	25	(19 - 30)	28	(22 - 43)	P = .15
	T2.2	19	(14 - 25)	6	(4 - 9)	P < .001 (ES = 0.83)
T3*		177	(159 - 208)	174	(153 - 203)	P = 0.55
RPE		7.0	(6.0 - 8.0)	7.0	(6.5 - 8.0)	P = 0.46

Table 1. Time of the Phases of the Test and Rating of Perceive Effort
Note: Approach rescue time for 100m swim (T1), tourniquet application time (T2) which was further divided into two phases: the first phase encompassed the time from gripping the tourniquet attached to the rescue tube to passing it around the arm and securing the strap with Velcro (T2.1), and the second phase involved adjusting the tourniquet by rotating the windlass or activating the ratchet (T2.2). Overall time from the start of the test until bleeding cessation (T3). Rating of perceived effort assessed using the modified Foster, et al scale ranging from 0 to 10 (RPE).
Abbreviations: T-CAT; Combat Application Tourniquet 7 Gen; T-OMNA, OMNA Marine Tourniquet; RPE, rating of perceived effort; ES, effect size.

	CAT Tourniquet		OMNA Tourniquet		P Value
Test Start					
100m Swim Time (seconds) *	131	(117 - 144)	135	(117 - 155)	P = .42
Checkpoint 1: Taking the Tourniquet					
Adjusts Band to Perimeter of Injured Limb (N)	15	(63%)	21	(88%)	P = .07
Sticks Tourniquet's Velcro (N)	23	(96%)	24	(100%)	P = 1.00
Distance from Tourniquet to Hemorrhage (cm)	4.0	(3.0 - 4.5)	4.0	(3.5 - 5.0)	P = .32
5-7cm Distance from Tourniquet to Hemorrhage (N)	5	(21%)	9	(38%)	P = .34
Checkpoint 2: Sticking the Velcro					
Makes Three Rotations of Tourniquet Cane/ Ratchet (N)	19	(79%)	15	(63%)	P = .34
Number of Rotations of Tourniquet Cane/ Ratchet	3.0	(3.0 - 4.5)	3.0	(3.0 - 4.0)	P = .52
Squeezes to Stop Critical Bleeding (N)	14	(58%)	21	(88%)	P = .039 (.39)
Secures the CAT Tourniquet Cane (N)	21	(88%)	–	–	–
Checkpoint 3: Stop the Bleeding					
Checks Distal Pulse (N)	15	(63%)	17	(71%)	P = .77
Marks Time of Tourniquet Placement (N)	15	(63%)	20	(83%)	P = .18
Stops the Bleeding Completely (N)	5	(21%)	11	(46%)	P = .15
Test End					

Table 2. Skills Actions Related to Tourniquet Application (N = 24)
Note: Continuous variables were described by median and interquartile range (Q1 - Q3), categorical variables (N) were described by absolute and relative frequencies. Continuous variables were compared with Wilcoxon signed rank test or Student's t test (*). In comparisons statistically significant, effect size was calculated with Rosenthal's r test or Cohen's d test (*). Classification: < 0.2 Trivial; 0.2-0.5 Small; 0.5-0.8 Moderate; 0.8-1.3 Large; and ≥ 1.3 Very large. Categorical variables were compared with McNemar test. In comparisons statistically significant, effect size was calculated with Cohen's g test. Classification: 0.05-0.15 Small; 0.15-0.25 Medium; and ≥ 0.25 Large.
Abbreviations: OMNA, OMNA Marine Tourniquet; CAT, Combat Application Tourniquet 7 Gen.

component, including factors such as the type of training, the environment in which they are applied, and the characteristics of the tourniquet. In aquatic environments, the use of tourniquets by civilians is not something new. A study by Scala, et al[3] analyzing traumatic injuries in the Hawaiian islands (USA) found that 75% of patients who suffered amputation or vascular injury had their bleeding controlled with an improvised tourniquet applied by a bystander.[3] Lifeguards often play a crucial role as first responders in aquatic incidents[14] with their competencies ranging from prevention to rescue and mitigation;[7] nevertheless, to the authors' knowledge, there have been no research studies conducted specifically with lifeguards, although studies have been conducted

Lifeguard	T-CAT			T-OMNA			
	Adjusts Tourniquet Band to Perimeter of Injured Arm	Fastens the Tourniquet Velcro	Complete Cessation of Bleeding	Adjusts Tourniquet Band to Perimeter of Injured Arm	Fastens the Tourniquet Velcro	Complete Cessation of Bleeding	
1	no	yes	no	yes	yes	yes	
2	no	yes	no	yes	yes	no	
3	no	yes	no	yes	yes	no	
4	yes	no	no	yes	yes	yes	
5	yes	yes	yes	yes	yes	no	
6	yes	yes	no	yes	yes	no	
7	yes	yes	no	yes	no	no	
8	yes	yes	no	yes	yes	no	
9	yes	yes	no	yes	yes	no	
10	yes	yes	yes	yes	yes	no	
11	no	yes	no	yes	yes	yes	
12	no	yes	no	yes	yes	no	
13	no	yes	no	yes	no	no	
14	no	yes	no	yes	no	no	
15	yes	yes	no	yes	yes	yes	
16	no	yes	no	yes	yes	no	
17	yes	yes	no	yes	yes	yes	
18	yes	yes	no	yes	yes	yes	
19	yes	yes	yes	yes	yes	no	
20	yes	yes	no	yes	yes	yes	
21	yes	yes	yes	yes	yes	yes	
22	yes	yes	no	yes	yes	yes	
23	yes	yes	no	yes	yes	yes	
24	yes	yes	yes	yes	yes	yes	
		5 of 24 21%			11 of 24 46%		P Value P = .15

Table 3. Summary of Performance of Each Participant in the Tourniquet Placement Steps
Abbreviations: T-CAT; Combat Application Tourniquet 7 Gen; T-OMNA, OMNA Marine Tourniquet.

on health care personnel.[15] The effectiveness and appropriate use of tourniquets in aquatic rescue scenarios warrant further investigation, and training programs tailored to the unique challenges of such environments could be essential to enhance outcomes and save lives.

Controlling prehospital hemorrhage in civilian aquatic environments is a crucial survival skill, as specialized medical assistance may be delayed for more than 60 minutes.[3] Therefore, the use of tourniquets should not be limited to tactical medicine, and its study should be extended to other settings given the significant knowledge gaps in remote or special environments. In fact, the International Liaison Committee on Resuscitation (ILCOR) emphasizes the lack of knowledge regarding techniques and training in this area.[16] In this study, the lifeguards received training for tourniquet use on land; however, the rate of hemorrhage control was low (between 21% and 46%). This could be explained by three hypotheses. Firstly, the lack of specific training and practice in tourniquet use in the water could have affected the rescuers' performance. During the tests, it was the first time they applied the tourniquet in the water, in a different environment and position from what they were used to, while trying to maintain a vertical position using swimming movements simultaneously. Secondly, the effort involved in the rescue and the resulting fatigue might have led to a loss of coordination and fine motor skills.[17,18] This situation could be further aggravated by conducting the rescue in cold water, which increases the physiological demand and perceived fatigue for swimmers.[19] Despite the effort lasting less than three minutes and covering a distance of no more than 100 meters, the lifeguards reported it as a very strenuous effort based on Foster's scale.[13] The third and final hypothesis, concerning the T-CAT tourniquet, suggests that these tourniquets are designed for single-use, and in this study were used multiple times, which may have limited their effectiveness in applying the required 3.5 turns to the windlass stick.

The distance between the tourniquet application and the wound is a crucial parameter in hemorrhage control training. In this simulation, the injured arm was partially submerged, and adjusting the band or placing it at the recommended distance might not have

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been easy. The refraction of light passing through water can alter visual perception, and the transparency of the water (low on the day of the test) could be another limiting factor because most rescuers placed the tourniquet at four centimeters instead of the recommended five to seven centimeters.[20]

The tourniquet manipulation time was under 30 seconds, which is acceptable and could be further improved with specific training.[21] However, an important finding relates to the tourniquet manipulation time, where the ratcheting closure of the aquatic model was statistically faster than the windlass rod of the T-CAT tourniquet. This could be attributed to the simplicity of the ratcheting mechanism, which requires less fine motor skills. It only requires a firm grip and coarse arm movements to tighten the ratchet, as opposed to the T-CAT tourniquet, which involves more intricate movements to wind the stick and secure it in place. These findings underscore the importance of considering specific challenges related to aquatic environments when designing and training for tourniquet use.

Limitations of the Study

Some limitations of this study should be noted to interpret the data with caution. Active bleeding simulators were used during the tests. While these simulators enhance the realism of the scene and standardize the intervention, the actual control of hemorrhage in a real-life scenario may differ significantly from a simulation and may involve emotional factors that could influence the rescuer's behavior. As mentioned, the lifeguards had prior training in using both tourniquet models, but the tests were the first time they applied them in an aquatic environment. Future studies should be directed towards designing a specific training and practice program in the water. The sample size was local, and the conditions of the aquatic environment were favorable, with no waves or adverse weather conditions. Lifeguards from other locations, with different training and varying aquatic environments, may yield different results.

Conclusion

The lifeguards in this study demonstrated the ability to use both tourniquet models during aquatic rescue and under conditions of fatigue in a reasonable amount of time. However, the overall success rate in achieving complete hemorrhage control was low. The tourniquet with a ratcheting closure system controlled the bleeding in less time compared to the windlass-style tourniquet. Additional research will help strengthen the understanding of tourniquet use in aquatic rescue scenarios and may provide more insights into optimizing their effectiveness in such environments.

References

1. Chalmers DJ, Morrison L. Epidemiology of non-submersion injuries in aquatic sporting and recreational activities. *Sports Med.* 2003;33(10):745–770.
2. Brophy RH, Bernholt DL. Aquatic orthopedic injuries. *J Am Acad Orthop Surg.* 2019;27(6):191–199.
3. Scala VA, Hayashi MS, Kaneshige J, Haut ER, Ng K, Furuta S. Shark-related injuries in Hawai'i treated at a Level 1 trauma center. *Trauma Surg Acute Care Open.* 2020;5(1): e000567.
4. Charlton NP, Swain JM, Brozek JL, et al. Control of severe, life-threatening external bleeding in the out-of-hospital setting: a systematic review. *Prehosp Emerg Care.* 2021;25(2):235–267.
5. Rossaint R, Bouillon B, Cerny V, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition. *Crit Care Lond Engl.* 2016;20:100.
6. Alonso-Algarabel M, Esteban-Sebastià X, Santillán-García A, Vila-Candel R. Tourniquet use in out-of-hospital emergency care: a systematic review. *Emerg Rev Soc Espanola Med Emerg.* 2019;31(1):47–54.
7. Szpilman D, Tipton M, Sempsrott J, et al. Drowning timeline: a new systematic model of the drowning process. *Am J Emerg Med.* 2016;34(11):2224–2226.
8. Barcala-Furelos R, Szpilman D, Palacios-Aguilar J, et al. Assessing the efficacy of rescue equipment in lifeguard resuscitation efforts for drowning. *Am J Emerg Med.* 2016;34(3):480–485.
9. Kragh JF, Dubick MA. Bleeding control with limb tourniquet use in the wilderness setting: review of science. *Wilderness Environ Med.* 2017;28(2S):S25–32.
10. OMNA Maritime Tourniquet. Florida USA: EEUU. 2019. http://www.omnainc.com/collections/maritime-tourniquets/. Accessed October 2023.
11. US Army. *Tactical Combat Casualty Care: Lessons and Best Practices*. CreateSpace Independent Publishing Platform; 2014.
12. OMNA Marine Tourniquet SCUBA Dive Buddy Application. 2019. Disponible en: https://www.youtube.com/watch?v=OCfYafUrm_E. Accessed October 2023.
13. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001;15(1):109–115.
14. Barcala-Furelos R, Aranda-García S, Abelairas-Gómez C, et al. [Occupational health recommendations for lifeguards in aquatic emergencies in the COVID-19 era: prevention, rescue, and resuscitation]. *Rev Esp Salud Publica.* 2020;94.
15. Sobrido-Prieto M, Martínez-Isasi S, Pérez-López M, Fernández-Méndez F, Barcala-Furelos R, Fernández-García D. Teaching and evaluation methods of the use of the tourniquet in severe limb bleeding among health care professionals: a systematic review. *Prehosp Disaster Med.* 2021;36(6):747–755.
16. Kleinman ME, Perkins GD, Bhanji F, et al. ILCOR scientific knowledge gaps and clinical research priorities for cardiopulmonary resuscitation and emergency cardiovascular care: a consensus statement. *Circulation.* 2018;137(22): e802–819.
17. Morales Toapanta BH, Pérez Ruiz ME, Pillajo Peralta MA, Bonilla López AR, Romero Frómeta E, Morán Pedroso L. [Biomechanical differences and effectiveness of the basketball free throw in optimal condition and in fatigue]. *Rev Cuba Investig Bioméd.* 2018;37(4):1–9.
18. Danna-Dos Santos A, Poston B, Jesunathadas M, Bobich LR, Hamm TM, Santello M. Influence of fatigue on hand muscle coordination and EMG-EMG coherence during three-digit grasping. *J Neurophysiol.* 2010;104(6):3576–3587.
19. Schnitzler C, Button C, Seifert L, Armbrust G, Croft JL. Does water temperature influence the performance of key survival skills? *Scand J Med Sci Sports.* 2018;28(3):928–938.
20. Deal VT, McDowell D, Benson P, et al. Tactical Combat Casualty Care February 2010. Direct from the Battlefield: TCCC lessons learned in Iraq and Afghanistan. *J Spec Oper Med Peer Rev J SOF Med Prof.* 2010;10(3):77–119.
21. Unlu A, Kaya E, Guvenc I, et al. An evaluation of combat application tourniquets on training military personnel: changes in application times and success rates in three successive phases. *BMJ Mil Health.* 2015;161(4):332–335.