TESE DE DOUTORAMENTO

# SKILLS ASSESSMENT IN DROWNING INCIDENTS BY RESCUERS

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**ESCOLA DE DOUTORAMENTO INTERNACIONAL DA UNIVERSIDADE DE SANTIAGO DE COMPOSTELA**

**PROGRAMA DE DOUTORAMENTO EN INVESTIGACIÓN CLÍNICA EN MEDICINA**

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En **Santiago de Compostela**, **29 de Maio de 2021**

**Sinatura electrónica**

# AUTORIZACIÓN DO DIRECTOR / TITOR DA TESE

**Skills assessment in drowning incidents by rescuers**

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Que a presente tese, correspóndese co traballo realizado por D/Dna. Roberto Jesús Barcala Furelos, baixo a miña dirección/titorización, e autorizo a súa presentación, considerando que reúne os requisitos esixidos no Regulamento de Estudos de Doutoramento da USC, e que como director desta non incorre nas causas de abstención establecidas na Lei 40/2015.

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En Santiago a 29 de 5 de 2021

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# ABBREVIATIONS

**[ENGLISH]**

ABCDE: Airway, Breathing, Circulation, Disability, Exposure approach

AED: Automated External Defibrillator

AVIR: Aquatic Victim-instead-of-rescuer Syndrome

BLS: Basic Life Support

BL: Blood Lactate

BMI: Body Mass Index

CC: Chest Compression

CPR: Cardiopulmonary Resuscitation

CO-CPR: Compression-only CPR

CV-CPR: Compression-to-Ventilation CPR

DM: Maximal Radial Muscle-Belly Displacement

EMG: Electromyography

EMS: Emergency Medical Services

ERC: European Resuscitation Council

ERC-GR: European Resuscitation Council Guidelines for Resuscitation

ES: Electro-stimulation

HEPA: High Efficiency Particulate Arresting

HIC: High Income Countries

HR: Heart Rate

IDRA: International Drowning Research Alliance

ILCOR: International Liaison Committee on Resuscitation

ILS: International Life Saving Federation

IQ: Interquartile Range

IRB: Inflatable Rescue Boat

JCR: Journal Citation Reports

La: Blood Lactate Concentration

LMIC: Low-Middle Income Countries

MM-only: Mouth to Mouth Resuscitation (only ventilations)

OHCA: Out-of-hospital Cardiac Arrest

PEB: Portable Emergency Bag

PICO: Participants, Intervention, Comparison, Outcome.

PPE: Protective Protection Equipment

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Q-CPR: Quality of Cardiopulmonary resuscitation

RPE: Rating of Perceive Effort

RWC: Rescue Water Craft

SARS-CoV-2: Acute Respiratory Syndrome Coronavirus-2

SEMES: Spanish Society of Emergency Medicine

TC: Muscle Contraction Time

TMG: Tensiomyography

V: Ventilation

WHO: World Health Organization

**[SPANISH/GALICIAN]**

BB: Reanimación Boca A Boca

EPI: Equipo de protección individual

MAR: Moto Acuática de Rescate

Q-RCP: Calidad Reanimación Cardiopulmonar

RCP: Reanimación Cardiopulmonar

TMG: Tensiomiografía

# LIST OF FIGURES

# LIST OF PUBLICATIONS

Thesis by compendium of publications indexed in the Journal Citation Report (article 41 of the Regulations for Doctoral Studies - USC).

Barcala-Furelos R, Graham D, Abelairas-Gómez C, Rodríguez-Núñez A. **Lay-rescuers in drowning incidents: A scoping review.** Am J Emerg Med. 2021 Jan 31;44:38–44 https://pubmed.ncbi.nlm.nih.gov/33578330/

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# ABSTRACTS

## ABSTRACT

### Background and purpose

Drowning is one of the leading causes of unintentional death worldwide. Prevention is the best strategy but it is not always sufficient to avoid the incident. When a person starts drowning, survival and prognosis will depend largely on the assistance of a rescuer. The objectives of this thesis were to analyze the interventions that both bystanders and professional rescuers have been known to use until now, in order to study the different strategies for the improvement of physiological conditions on the basis of simulation-controlled studies and to evaluate the optimization of resuscitation techniques on board rescue boats, both before and during the COVID-19 pandemic.

### Material and methods

Six scientific publications make up this thesis. The first two papers are conceptual and descriptive, namely: a systematic literature review (PRISMA) and an expert consensus guide based on the COVID-19 literature review. The remaining 4 articles are controlled simulation studies with lifeguards, innovative in methodology, in which physiological, perceptual and skill aspects were analyzed during cardiopulmonary resuscitation (CPR) in case of drowning.

**Results**

Four profiles of lay rescuers have been identified, with different skill levels, and risk gradation has been established according to the rescue technique used.

In professional lifeguards, the effect of electrostimulation (ES) on the recovery process after a rescue was found to be better than passive recovery.

The feasibility of cardiopulmonary resuscitation maneuvers has been verified by navigating on a rescue water craft (RWC).

In situations with risk of airborne transmission of aerosols containing infectious agents, the use of plastic blankets improves intervention start times without reducing the quality of CPR.

**Conclusions**

The conclusions related to the hypotheses are summarized in the following three paragraphs:

There are different profiles of lay-rescuers. There is no scientific description of recommended water rescue techniques for lay-people; therefore in general the lay-rescuer should not enter the water to attempt a rescue. However, lay-rescuers with aquatic experience who are in the water (e.g. surfers) can be a great asset in drowning mitigation.

In relation to professional lifeguards, initiating CPR of the drowning victim early is possible on land and on a rescue vessel by adapting known techniques to the space, rescuer position and sea conditions. The use of personal protective equipment (PPE) has a number of advantages as well as limitations in aquatic environments. The use of a plastic blanket may be an alternative to delay the start of maneuvers without diminishing the CPR quality.

Active recovery methods designed for professional rescuers promote faster physiological readjustment. Electrostimulation may be an alternative for recovery after a physically demanding rescue.

**Key words**

Drowning, bystander, lifeguards, cardiopulmonary resuscitation, physiological recovery, rescue boats, COVID-19.

## RESUMEN

### Antecedentes y propósito

El ahogamiento es una de las principales causas de muerte no intencional a nivel mundial. La prevención es la mejor estrategia pero no siempre es suficiente para evitar el incidente. Cuando una persona comienza a ahogarse, la supervivencia y pronóstico van a depender en gran medida del auxilio de un rescatador. Los objetivos de esta tesis fueron analizar las intervenciones conocidas hasta el momento de testigos (rescatadores legos) y socorristas profesionales, y analizar en base a estudios controlados las diferentes estrategias de recuperación tras el rescate, estudiar la viabilidad de técnicas de reanimación a bordo de embarcaciones de rescate y evaluar diferentes equipos de protección personal para la reanimación cardiopulmonar (RCP) durante la pandemia COVID-19.

### Material y métodos

Seis publicaciones científicas conforman esta tesis. Los dos primeros trabajos son conceptuales y descriptivos: una revisión sistemática de la literatura (PRISMA) y una guía de consenso de expertos basada en la revisión de la literatura en tiempos de COVID-19. Los restantes cuatro artículos son estudios controlados de simulación con socorristas. Estos trabajos son metodológicamente innovadores, en los que se analizaron aspectos fisiológicos, perceptivos y de habilidades durante la RCP en ahogamiento.

**Resultados**

Se han identificado cuatro perfiles de rescatadores legos, con diferentes niveles de habilidad y se ha establecido una clasificación del riesgo en función de la técnica de rescate utilizada.

En socorristas profesionales, el efecto de la electro-estimulación(ES) logró mejores resultados en el proceso de recuperación después del rescate que la recuperación pasiva.

Se ha verificado la viabilidad de las maniobras de RCP en una moto acuática de rescate. La calidad de las maniobras fue aceptable, rondando el 60% navegando a 20 nudos.

En la situación de riesgo de contagio por aerosoles durante la RCP en tiempos de COVID-19, el uso de mantas plásticas puede ser una alternativa a considerar por los socorristas, ya que acorta el tiempo de inicio de las maniobras sin disminuir la calidad de la RCP. Este sistema de protección puede ser usado tanto en la arena como en las embarcaciones de rescate.

**Conclusiones**

Las conclusiones relacionadas con las hipótesis se sumarizan en los siguientes tres párrafos:

Existen cuatro perfiles de rescatadores legos. No existe descripción ni recomendación científica sobre las técnicas de rescate empleadas por rescatadores legos, por lo tanto, de forma genérica el testigo sin

experiencia no debe entrar en el agua para intentar un rescate, sin embargo, aquellos rescatadores que sin entrenamiento formal cuentan con experiencia acuática, están dentro del agua en el momento del incidente y disponen de material de flotación (ej. surfistas), pueden ser un gran activo en la mitigación del ahogamiento.

En relación a los socorristas profesionales, iniciar la RCP del ahogado de forma precoz es posible en tierra y en una embarcación de rescate, adaptando las técnicas al espacio, posición del rescatador y condiciones marítimas. El uso de equipos de protección personal (EPI) supone una serie de ventajas y también limitaciones en entornos acuáticos. El uso de mantas de plástico puede ser una alternativa real para no demorar el inicio de las maniobras y no supone una disminución de la calidad de la RCP.

Los métodos de recuperación activos diseñados para socorristas, promueven un reajuste fisiológico más rápido. La ES puede ser una gran alternativa de recuperación después de un rescate acuático con gran demanda física.

**Palabras Clave**

Ahogamiento, testigo, socorristas, reanimación cardiopulmonar, recuperación fisiológica, embarcaciones de rescate, COVID-19.

## RESUMO

### Antecedentes e propósito

O afogamento é unha das principais causas de morte non intencional a nivel mundial. A prevención é a mellor estratexia pero non sempre e suficiente para evitar o incidente. Cando unha persoa comeza a afogarse, a supervivencia e o pronóstico van a depender en gran medida do auxilio dun rescatador. Os obxectivos desta tese foron analizar as intervencións coñecidas ata o momento de testemuñas (rescatadores legos) e socorristas profesionais, e analizar en base a estudos controlados as diferentes estratexias de recuperación tralo rescate, estudar a viabilidade de técnicas de reanimación a bordo de embarcacións de rescate e avaliar diferentes equipos equipos de protección persoal para a reanimación cardiopulmonar (RCP) durante a pandemia COVID-19.

### Material e métodos

Seis publicacións científicas conforman esta tese. Os dous primeiros traballos son conceptuais e descriptivos: unha revisión sistemática da literatura (PRISMA) e unha guía de consenso de expertos baseada na revisión da literatura en tempos de COVID-19. Os restantes catro artigos son estudos controlados de simulación con socorristas. Estes traballos son metodolóxicamente innovadores e analizaron aspectos fisiolóxicos, perceptivos e de habilidades durante a RCP en afogamento.

## Resultados

Identificáronse catro perfis de rescatadores legos, con diferentes niveis de habilidade e estableceuse unha graduación do risco en función da técnica de rescate utilizada. En socorristas profesionais, o efecto da electro-estimulación (ES), acadou mellores resultados no proceso de recuperación despois do rescate que a recuperación pasiva.

Verificouse a viabilidade das manobras de RCP nunha moto de agua de rescate. A calidade das manobras foi aceptable, rondando o 60% navegando a 20 nós. Nas situación de risco de contaxio por aerosois durante a RCP en tempos de COVID-19, o uso de mantas plásticas pode ser unha alternativa a considerar polos socorristas, xa que acorta o tempo de inicio das manobras sen disminuir a calidade da RCP. Este sistema de protección pode ser usado tanto na area como en embarcacións de rescate.

## Conclusións

As conclusións relacionadas coas hipótesis sumarizanse nos siguientes tres parágrafos:

Existen catro perfís diferentes de rescatadores legos. Non existe descripción nin recomendación científica sobre as técnicas de rescate empregadas por rescatadores legos, polo tanto, de forma xenérica a testemuña sen experiencia non debe entrar na auga para intentar un rescate, sen embargo aqueles rescatadores que sen entrenamento formal contan con experiencia acuática, que están dentro del agua no momento

do incidente e que dispoñen de material de flotación (ex. surfistas), poden ser un gran activo na mitigación do afogamento.

En relación aos socorristas profesionais, iniciar a RCP do afogado de maneira precoz e posible, en terra e tamén nunha embarcación de rescate, adaptando as técnicas ao espazo, posición do rescatador e condicións marítimas. O uso de equipos de protección personal (EPI) supón unha serie de vantaxes e tamén de limitacións en entornos acuáticos. O uso de mantas de plástico pode ser unha alternativa real para non demorar o inicio das manobras e non supón unha disminución da calidade de RCP. Os métodos de recuperación activos deseñados para socorristas, promoven un reaxuste fisiolóxico máis rápido. A ES pode ser unha alternativa de recuperación despois dun rescate acuático con gran demanda física.

**Palabras Chave:** Afogamento, testemuña, socorristas, reanimación cardiopulmonar, recuperación fisiolóxica, embarcaciones de rescate, COVID-19.

# SUMMARY IN SPANISH

# SUMARIO EN ESPAÑOL

# SUMMARY IN SPANISH

*Nota. Este sumario es una versión reducida del documento principal en lengua inglesa. Las referencias bibliográficas han sido citadas en el manuscrito en inglés.*

## INTRODUCCIÓN

El ahogamiento es un problema importante de salud pública y es responsable directo de casi 300.000 muertes anuales en todo el mundo. Afecta especialmente a niños y tiene un especial impacto en los países de bajos o medios recursos. A nivel global representa la tercera causa de muerte por daño no intencional y supone el 7% de todas las muertes relacionadas con lesiones.

En España se estima que 400 personas fallecen por ahogamiento cada año. El ahogamiento se define como *"el proceso por el que se experimenta una imposibilidad para respirar por sumersión o inmersión en un fluido"*, y de forma genérica, su resultado puede ser la muerte o supervivencia con o sin morbilidad. Se considera que el ahogamiento está infravalorado y a menudo se ha referido a la *"Metáfora del Iceberg"*. Un ejemplo de esta metáfora se refleja en los datos comparativos; por cada persona ahogada que requirió de atención médica, otras seis tuvieron que ser rescatadas.

La prevención es la estrategia más importante y la más efectiva en el balance coste/beneficio, por ello numerosas publicaciones recomiendan focalizar los esfuerzos en las tareas preventivas del ahogamiento, sin embargo, los datos epidemiológicos indican que todavía queda un largo camino hacia una prevención lo suficientemente efectiva. Es necesario por tanto estudiar, entender y comprender los mecanismos desencadenantes, los perfiles de los ahogados y las habilidades y estrategias de los socorristas profesionales para atender a las personas que sufren un incidente en el medio acuático.

Las circunstancias que envuelven al ahogamiento a menudo suelen ser multifactoriales, pero generalmente tienen que ver con la omisión de las medidas de prevención o asumir conductas de riesgo. Aún así, el proceso de ahogamiento es silencioso, sutil y todavía no está suficientemente estudiado, de ahí la importancia de la investigación en todos los aspectos del ahogamiento. En este punto, conocer cómo los rescatadores (legos o profesionales) afrontan un incidente acuático, debe ser uno de los retos de la ciencia del ahogamiento.

Un testigo que presencia un ahogamiento y decide prestar auxilio es lo que conocemos como “rescatador lego” y se define como la persona que sin ser profesional o tener un conocimiento específico intenta un rescate acuático. Pueden existir diferentes tipos de rescatadores legos en función de su conocimiento y competencias.

En cambio, los socorristas son personas que han completado un entrenamiento formal y son competentes para prevenir incidentes, rescatar y aplicar primeros auxilios en entornos acuáticos.

Tanto testigos como profesionales son parte de la solución, por tanto evaluar las capacidades y limitaciones de cada perfil, y proponer las mejores prácticas fue el origen de esta tesis doctoral. Estos propósitos se han visto alterados y por tanto modificados con la nueva situación de salud. En el año 2019 se produce una de las mayores alertas epidemiológicas de los últimos cien años. El *Acute Respiratory Syndrome Coronavirus-2* (SARS-CoV-2). El mundo viviría en Europa el primer verano de la Era-Covid en 2020. La problemática para los socorristas es que sus intervenciones raramente se dan en otros contextos médicos, y en este momento todavía se ha complicado más por la COVID-19.

Esta tesis pretende compilar las características, condiciones y efectos de las habilidades de los socorristas (legos o profesionales) y mostrar las nuevas aportaciones adaptadas a tiempos de COVID-19.

## HIPÓTESIS

H1. Los rescatadores legos tienen características, motivaciones y habilidades específicas que pueden ser identificadas en la literatura científica.

H2. Las técnicas para la reanimación en caso de ahogamiento pueden ser adaptadas y optimizadas para situaciones todavía más especiales (en embarcación de rescate o con uso de Equipos de Protección Individual (EPI) durante la era COVID-19).

H3. La recuperación fisiológica del socorrista tras el rescate acuático puede acortarse con estrategias utilizadas en el deporte profesional.

**OBJETIVOS**

O1. Identificar los diferentes perfiles rescatadores legos descritos en la literatura científica.

O1.1. Clasificar las diferentes técnicas realizadas por rescatadores legos.

O1.2. Identificar el perfil y competencia de los rescatadores legos.

O2. Evaluar las habilidades de los rescatadores en diferentes contextos y situaciones de la reanimación en ahogamiento.

O2.1. Evaluar la viabilidad y calidad de la reanimación en Moto Acuática de Rescate Acuática (MAR).

O2.2. Analizar las habilidades de reanimación con EPI.

O2.3. Comparar diferentes sets de EPI durante la reanimación a bordo de una embarcación.

O3. Analizar estrategias de recuperación fisiológica tras la intervención del socorrista.

O3.1. Analizar la recuperación pasiva tras un rescate acuático.

O3.2. Comparar el efecto de la electro-estimulación (ES) sobre la recuperación tras el rescate acuático.

## METODOLOGÍA

Esta tesis doctoral está compuesta de 6 publicaciones que han seguido diferentes metodologías, adaptadas a los objetivos establecidos en cada subestudio. El conjunto de artículos y el ámbito del socorrismo que abarca, puede apreciarse en la *figura 1a*.

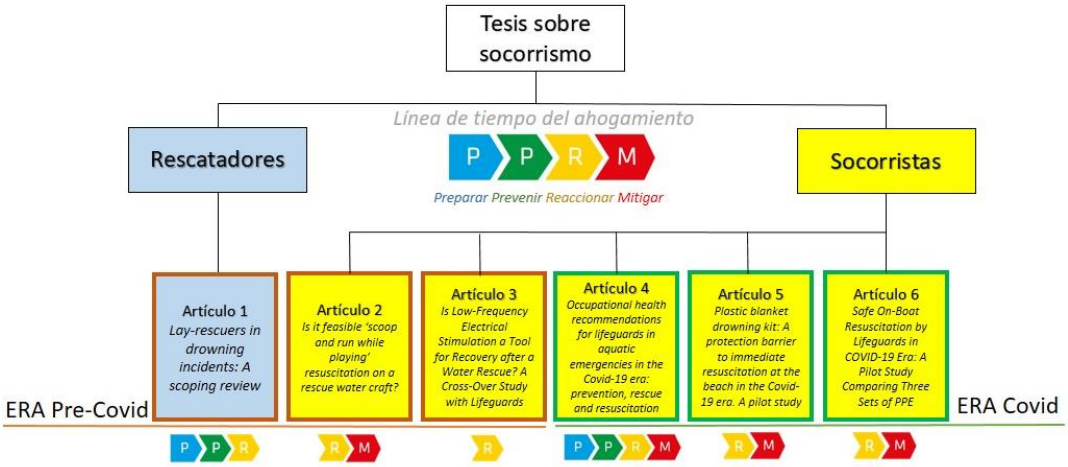


Figura 1a. Diagrama de flujo del contenido de la Tesis. Evaluación de las habilidades de los rescatadores en los incidentes acuáticos.

Dos de los artículos son revisiones, basados en evidencias y proponiendo una síntesis de los resultados. El estudio titulado *"Lay-rescuers in drowning incidents: A scoping review"* es una revisión sistemática de la literatura siguiendo la metodología PRISMA. El estudio titulado *"Occupational health recommendations for socorristas in aquatic emergencies in the Covid-19 era: prevention, rescue and resuscitation"* se presenta en forma de recomendaciones basadas en evidencias. La metodología para realizar este artículo también siguió una metodología PRISMA, pero la forma de presentar el manuscrito, por la propia finalidad del contenido, sigue la estructura de recomendación científica.

Los cuatro restantes estudios *"Is it feasible 'scoop and run while playing' resuscitation on a rescue water craft? A randomized simulation study with socorristas"*, *"Plastic blanket drowning kit: A protection barrier to immediate resuscitation at the beach in the Covid-19 era. A pilot study"*, *"Safe on-boat resuscitation by socorristas in Covid-19 Era. A pilot study comparing three sets of protective personal equipment"*, *"Is low-frequency Electrical Stimulation a tool for recovery after a Water Rescue? A Cross-Over Study with Socorristas"*, siguen una metodología cuasi-experimental. Son estudios cuantitativos, aleatorizados y transversales. El análisis de los datos fue realizado con el software estadístico SPSS (IBM Corp., Chicago, IL, USA). Mediante comparaciones por pares (pruebas paramétricas –*TTest/Anova*- o no paramétricas –*Wicolxon test*-) de dos o más factores. Los estudios

presentan medias, desviaciones típicas, intervalos de confianza (95%), frecuencias y tamaño del efecto. Se estableció un nivel de significatividad de $p<0.05$ para todos los análisis.

## RESULTADOS DE LAS PUBLICACIONES

**Artículo 1.** Lay-rescuers in drowning incidents: a scoping review.

[Rescatadores legos en incidentes acuáticos: una revisión de la literatura]

**Objetivo.** Muchas víctimas de incidentes acuáticos son legos que tratan de rescatar a otro. Esta revisión tiene como objetivo identificar las técnicas y materiales más seguros (improvisados o diseñados específicamente) para que un testigo no capacitado los use cuando intente un rescate acuático.

**Método.** Una muestra de 249 trabajos fue incluida en la búsqueda bibliográfica, en los que finalmente se seleccionaron 19 siguiendo la metodología PRISMA y se añadieron 3 trabajos presentados en congresos internacionales y revisados por pares. Se incluyeron un total de 22 documentos a la síntesis cualitativa.

**Resultados**. La ubicación geográfica, el nivel económico, la condición física o la experiencia pueden variar el perfil de los rescatadores legos y la forma de realizar un rescate acuático de manera segura. Se

identificaron cuatro perfiles de rescatadores legos: 1) Niños que rescatan a niños en países con bajos y medios ingresos, 2) Adultos que rescatan a adultos o niños, 3) Testigos con alguna experiencia y entrenamiento en rescate, 4) Testigos con motivaciones culturales o profesionales. Tres tipos de técnicas utilizadas por los diferentes perfiles de rescatadores legos: a) técnicas sin contacto para rescates desde tierra: lanzamiento y alcance, b) técnicas sin contacto para rescate mediante material con flotación y, c) técnicas de rescate con contacto dentro del agua: nadar y remolcar con o sin aletas.

**Conclusión**. La recomendación de los expertos es que la técnica más segura para rescatadores legos es intentar un rescate usando una rama, ropa o algún material de flotación, sin entrar en el agua. Sin embargo, aún con la recomendación de rescates sin contacto desde tierra, existe una tendencia global a intentar rescates desde el agua, sin que hasta el momento haya evidencia de cuál técnica o procedimiento puede contribuir a un rescate seguro. Deben considerarse estrategias de formación para legos.

**Artículo 2.** Is it feasible 'scoop and run while playing' resuscitation on a rescue water craft? a randomized simulation study with lifeguards.

[Es posible rescatar y trasladar reanimando en una moto de agua. un estudio aleatoriazado de simulación con socorristas]

**Objetivo:** El tiempo de respuesta es un factor predictivo para la supervivencia de las víctimas de ahogamiento. Las motos acuáticas de rescate (MAR) son embarcaciones muy habituales en las operaciones de salvamento. El objetivo de este estudio fue analizar la viabilidad de administrar ventilaciones boca a boca y / o resucitación cardiopulmonar (RCP) efectivas en MAR mientras se navega a diferentes velocidades.

**Método:** Se utilizó un diseño cuasi-experimental cruzado para evaluar durante un minuto la viabilidad de la ventilación Boca a Boca (BB) y la RCP tanto en tierra (playa) como navegando a dos velocidades diferentes 5 y 10 nudos con mar en calma. Las referencias de RCP de calidad (Q-RCP) fueron las directrices del ERC de 2015.

**Resultados:** Se incluyeron los datos obtenidos de 13 socorristas que completaron 78 test de RCP. Las habilidades de ejecución de solo BB alcanzaron 69,7% ± 40,4 para 5 nudos y 60,0% ± 41,8 para 10 nudos (p = 0,59). Para la RCP estándar (compresiones y ventilaciones), el resultado fue 74,4% ± 24,2 y 68,5% ± 23,9 respectivamente. La calidad de la BB y la RCP disminuyó no significativamente, mientras navegaba a 5 nudos y 10 nudos [(Q-BB; 5 nudos: 59,9% ± 37,8 vs.10 nudos: 43,2% ± 41,4, p = 0,42) (Q-RCP ; 5 nudos: 64,8% ± 21,2 y 10 kn: 60,6% ± 21,0, p = 0,44)]. Las variables de solo BB y compresiones torácicas fueron significativamente peores en MAR en comparación con la reanimación en la playa (p <0,05). Se observó una tendencia a mejores resultados por parte de los socorristas que se entrenaron previamente en MAR.

**Conclusiones:** Las técnicas de reanimación a bordo de MAR son factibles y por tanto podrían ser una opción para los socorristas cuando su formación, las condiciones del mar, la distancia y las características de la víctima lo permitan. Las maniobras de RCP pueden ser muy efectivas a 10 nudos, tanto para MM solo como para RCP; sin embargo, la calidad de las ventilaciones empeora drásticamente al aumentar la velocidad.

**Artículo 3.** Is low-frequency electrical stimulation a tool for recovery after a water rescue? a cross-over study with lifeguards.

[¿Es la electro-estimulación de baja frecuencia una herramienta para la recuperación después de un rescate acuático? un estudio cruzado con socorristas]

Este estudio tuvo como objetivo evaluar en qué grado la electro-estimulación (ES) transcutánea mejoró la recuperación después de un rescate acuático simulado. En este estudio participaron veintiséis socorristas. El rescate consistió en nadar 100 m con aletas y tubo de rescate: 50 m de aproximación de nado y 50 m de remolque de una víctima simulada. La concentracion de lactato en sangre, el esfuerzo percibido (RPE) y las propiedades contráctiles de los músculos se evaluaron al inicio del estudio, después del rescate en el agua y después del protocolo de recuperación pasiva (PR) o activa con ES. La tensiomiografía, el RPE y los niveles basales de lactato en sangre indicaron equivalencia entre ambos grupos antes del rescate. No hubo

cambios en la tensiomiografía antes y después de la recuperación y no hubo diferencias entre los protocolos de recuperación (pasivo o con ES). El RPE general, el RPE de piernas y el RPE de brazos después de ES (media ± DE; 2,7 ± 1,53, 2,65 ± 1,66 y 2,30 ± 1,84, respectivamente) fueron moderadamente más bajos que después de PR (3,57 ± 2,4, 3,71 ± 2,43 y 3,29 ± 1,79, respectivamente) (p = 0,016, p = 0,010, p = 0,028, respectivamente). Hubo un nivel de lactato en sangre significativamente más bajo después de la recuperación con ES que en PR (media ± DE; 4,77 ± 1,86 mmol • L-1 frente a 6,27 ± 3,69 mmol • L-1; p = 0,045). La ES de baja frecuencia inmediatamente después de un rescate en el agua es una estrategia de recuperación eficaz para eliminar la concentración de lactato en sangre.

**Artículo 4.** Occupational health recommendations for lifeguards in aquatic emergencies in the covid-19 era: prevention, rescue and resuscitation.

[Recomendaciones de salud laboral para socorristas ante emergencias acuáticas en la era covid-19: prevención, rescate y reanimación]

El síndrome respiratorio agudo severo (SARS-CoV-2), que causa la enfermedad por coronavirus 2019 (Covid-19), es altamente contagioso. Los socorristas son la primera línea de respuesta en las emergencias acuáticas y van a sufrir una fuerte exposición al riesgo este primer verano de la era Covid-19, por lo que su salud laboral debe ser replanteada en su práctica profesional durante la nueva normalidad. La

principal medida de salud pública para evitar ahogamientos es la prevención, pero cuando esta falla y se requiere la asistencia o el rescate, en la mayor parte de las intervenciones el distanciamiento no será posible. La limitación de los equipos de protección personal (EPI) para el rescate es una realidad que debe conocerse y que puede afectar a la salud del socorrista. Se realizó una revisión de la literatura actual orientada a evitar o minimizar el riesgo de contagio en las intervenciones realizadas por rescatadores en la era Covid-19. Este artículo ofrece una información estructurada sobre la prevención del contagio en los socorristas, los riesgos potenciales, los EPI disponibles y las recomendaciones para su adecuado uso durante los rescates o la atención prehospitalaria en los entornos acuáticos.

**Artículo 5.** Plastic blanket drowning kit: a protection barrier to immediate resuscitation at the beach in the covid-19 era. a pilot study.

[kit de manta de plástico para ahogamiento: una barrera de protección para la reanimación inmediata en la playa durante la era covid-19. un estudio piloto]

**Objetivo:** Presentación de un nuevo equipamiento para socorristas simple y económico, compuesto por una mascarilla facial pre-ensamblada a una manta de plástico y a un filtro HEPA, lo que puede ofrecer un significativo ahorro de tiempo y otras ventajas para reducir el riesgo de transmisión del COVID-19 en los primeros minutos de la

RCP tras un rescate acuático, eliminando el impacto negativo en la demora de la ventilación.

**Método:** Se realizó un estudio piloto para determinar la viabilidad del kit premontado de mascarilla y filtro HEPA adaptado sobre una manta plástica preestablecida. El primer paso consistió en lavarse las manos, ponerse gafas y guantes de seguridad como primer equipo de protección personal (EPI) y luego cubrir a la víctima con una manta plástica montada. El segundo paso consistió en 10 min de reanimación cardiopulmonar (RCP) con EPI y manta plástica, siguiendo las recomendaciones técnicas para la ventilación durante el COVID-19.

**Resultados:** Diez socorristas participaron en el estudio piloto. El tiempo promedio para usar EPI y colocar el kit premontado sobre la víctima fue de 82 s [IC 58-105]. Después de 10 min, la calidad de la reanimación (Q-RCP) fue del 91% [87-94]. Las calidad de las compresiones torácicas fue de un 22% mejores que las ventilaciones. La mayoría de los socorristas (60%) consideraron que colocar la manta de plástico sobre la víctima en la playa era algo simple o muy simple.

**Conclusiones:** Las técnicas de reanimación en la playa durante la era COVID-19 ha incrementado la complejidad para el uso correcto de EPI. La manta plástica añade un plus para la ventilación lo que podría ser una nueva alternativa a considerar por los socorristas para realizar ventilaciones mientras reducen el riesgo de transmisión.

**Article 6.** Safe on-boat resuscitation by lifeguards in covid-19 era. a pilot study comparing three sets of protective personal equipment.

[reanimación segura a bordo realizada por socorristas en la era covid-19. un estudio piloto comparando tres sets de equipamiento personal de protección]

**Introducción:** La reanimación a bordo puede ser aplicada por socorristas en embarcaciones de rescate. A raíz de la aparición del Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-COV-2) y las recomendaciones para el uso de equipo de protección personal (EPI), los procedimientos prehospitalarios han sido reevaluados. El objetivo de este estudio fue determinar como el uso de EPI influye en el tiempo de preparación necesario antes de comenzar la reanimación (RCP) y en la calidad de la reanimación cardiopulmonar (Q-RCP) en una embarcación de rescate semirrígida.

**Métodos:** Se realizaron tres pruebas de RCP con 14 socorristas, agrupados en parejas, con diferentes EPI: (1) EPI Básico (B-EPI): guantes, mascarilla y gafas protectoras; (2) EPI completo (F-EPI): B-EPI + un delantal impermeable; y (3) EPI básico + manta plástica (B + EPI). Se realizó una RCP a bordo utilizando una bolsa-válvula-máscara (BVM) y un filtro de aire de partículas de alta eficiencia (HEPA) navegando a 20 km / hora.

**Resultados:** el uso de B-EPI lleva menos tiempo y es significativamente más rápido que el F-EPI (B-EPI 17 [SD = 2]

segundos versus F-EPI 69 [SD = 17] segundos; P = 0,001), y el uso de B + EPI es ligeramente superior (B-EPI 17 [SD = 2] segundos frente a B + EPI 34 [SD = 6] segundos; P = 0,002). El QCPR se mantuvo similar en los tres escenarios (P> .05), alcanzando valores superiores al 79%.

**Conclusión:** El uso de EPI durante la reanimación a bordo es factible y no interfiere con la calidad cuando es realizado por socorristas entrenados. El uso de una manta de plástico podría ser una alternativa rápida y fácil para ofrecer protección adicional a los socorristas durante la RCP en un bote de rescate.

## DISCUSIÓN

Esta tesis realizada según la modalidad de compendio de publicaciones tuvo como principales objetivos, analizar los perfiles de rescatadores (tanto legos como socorristas), y profundizar en diferentes estrategias educativas, fisiológicas y de reanimación, además de implementar conductas seguras mediante una serie de recomendaciones adaptadas a tiempos de COVID-19.

Sus principales hallazgos fueron:

a) Existen cuatro perfiles dominantes de rescatadores legos, con diferente riesgo en función de su edad, procedencia, motivaciones y experiencia.
b) El rescate acuático es fisiológicamente muy exigente. Supone gran demanda física y requiere por tanto una recuperación

adecuada. Esta recuperación puede ser acelerada con métodos procedentes del deporte profesional (p.ej. foam roller/electro-estimulación).

c) El uso de mantas de plástico puede ser una alternativa rápida y eficaz en la RCP realizada por socorristas, tanto en tierra como en embarcaciones de rescate, sin demorar el inicio de las ventilaciones.

*Rescatadores legos, perfiles y técnicas*

Para los testigos no profesionales, hasta ahora se ha recomendado que ante un incidente acuático no deben entrar en el agua para intentar un rescate, sin embargo esta recomendación entra en conflicto con numerosas circunstancias; a) localización del incidente (la mayoría entre los 50 y 100 m), b) relación de parentesco con la víctima y c) aspectos culturales como por ejemplo el caso de los surfistas australianos que contribuyen notablemente a los salvamentos en playas no vigiladas. El consenso de expertos apoya que si es lego, sólo se recomienda el auxilio desde fuera del agua siguiendo la secuencia "*reach, throw and don´t go* [alcanzar, lanzar y no ir]". Aun así, la conducta humana más repetida es intentar el rescate, lo que en numerosas ocasiones provoca lo que se ha definido como síndrome *Aquatic-Victim-Instead-of-Rescued*(AVIR) [víctima acuática en lugar de rescatador], que consiste en el intento de rescate de una persona que se está ahogando, convirtiéndose el rescatador también en víctima durante el intento. Ante esta conducta impulsiva y para mitigar las

consecuencias de un rescate inexperto, algunos científicos australianos sugieren que todo bañista tenga en su material de playa *"tools for heroic acts"*[herramientas para actos heroicos]. Este posicionamiento es ciertamente discutible, aunque también muy realista. Por tanto para rescatadores legos (P) en que medida existen técnicas de rescate(I), en comparación con no intentar el rescate (C), y que no ponga el riesgo ni exponga a un mayor peligro al rescatador(O)? Es precisamente esta PICO *question* la que ha tratado de responder el primer artículo de esta tesis doctoral.

Se encontraron cuatro tipos de rescatadores legos. Para dos de los perfiles: *1) Niños rescatando niños* y *2) Adultos rescatando adultos o niños*, es posible que la educación juegue un papel fundamental para enfrentarse al riesgo con la mayor seguridad posible. Hasta ahora las propuestas científicas se han basado en la prevención del incidente, pero no hay referencias de cómo controlar los impulsos y tomar decisiones correctas en el momento del rescate.

La revisión muestra otros dos tipos de rescatadores legos con motivaciones culturales, con experiencia o con educación en la seguridad del medio acuático como los surfistas, que contribuyen notablemente a los rescates de bañistas en apuros, especialmente en playas no vigiladas.

*Socorristas profesionales; Rescate, reanimación y recuperación.*

Los socorristas son los profesionales encargados de la prevención, vigilancia e intervención en caso de incidente acuático. Su cometido es proveer unos altos estándares en calidad asistencial, con el objetivo de evitar y/o tratar cualquier contingencia en el medio acuático y su entorno.

Dentro de este campo de la literatura, hay un estudio que tiene un valor especial, ya que abordó por primera vez la viabilidad para realizar la reanimación boca a boca a bordo de una MAR.

Este estudio parte de dos conceptos vitales: ganar tiempo y tratar la hipoxia, por lo que se propone una respuesta a un debate clásico sobre el tratamiento pre-hospitalario en situaciones especiales de "*stay and play*" [tratar en el sitio] or "*scoop and run*" [evacuar rápidamente].

La mejora de habilidades tiene como base el entrenamiento, tanto técnico como físico, ya que el salvamento tiene una alta demanda fisiológica. Un hallazgo común en todos los estudios sobre socorristas es la fatiga en sus intervenciones. Esto ocurre tanto en embarcaciones como especialmente tras rescates acuáticos a nado.

Los socorristas deben estar en buena forma física para afrontar los rescates, y a diferencia del salvamento deportivo, en el socorrismo profesional tras realizar un rescate se debe seguir trabajando.

Uno de los retos de esta tesis, fue analizar cómo se puede atenuar el efecto de la fatiga aguda en los socorristas, buscando estrategias que ayuden a su recuperación sin que supongan una interrupción de sus labores profesionales. Es en este momento, basado en un equipo multidisciplinar de trabajo con socorristas, médicos, enfermeros, educadores físicos y fisioterapeutas, cuando se plantea la electroestimulación para ser usada tras el rescate acuático.

Se realizó un estudio controlado colaborativo entre la Universidad de Vigo, la Universidad de Santiago de Compostela y la Universidad de Coimbra, en la localidad del litoral portugués de Figueira da Foz. Tras un rescate de 100m, se aplicó una corriente de onda bifásica a 5 Hz, con una duración de 0.25 milisegundos. El tiempo de electroestimulación fue de 20min. La localización de los electrodos fue en los cuádriceps de ambas piernas, basado en que los socorristas realizaron el rescate con aletas, y la literatura científica muestra que durante la patada de crol con aletas, el músculo con mayor implicación es el *recto femoral*.

Los resultados obtenidos, mostraron valores fisiológicos a tener en cuenta. La electro estimulación redujo significativamente la disminución de la concentración de lactato y mostró una tendencia hacia una menor fatiga percibida aunque no logró valores significativos ($p>0.05$).

*SARS-COV-2 y socorrismo*

Tras el confinamiento decretado por el Gobierno de España, y mientras se empezó a doblegar la primera ola, entramos en mayo/junio, justo el comienzo de la temporada de verano y nadie había pensado en los socorristas, ni en su entrenamiento para afrontar el primer verano de la Era COVID-19, ni en el uso de EPI en la playa, ni en las modificaciones técnicas que requieren los procedimientos de salvamento y reanimación del ahogado.

Desde el grupo de trabajo de socorrismo de la Sociedad Española de Medicina de Emergencias (SEMES) junto con otros investigadores del ahogamiento, se creó un grupo de trabajo para promover unas recomendaciones de autoprotección e intervención para socorristas, que finalmente fue publicado en junio del 2020 en la Revista Española de Salud Pública, del Ministerio de Sanidad.

Este grupo elaboró una guía organizada en cuatro apartados: 1) Prevención del contagio, cribado de positivos y riesgos para el socorrista, 2) Equipo de protección individual (EPI). Posibilidades y limitaciones, 3) Reacción ante el ahogamiento. Rescate acuático. 4) Mitigación: atención prehospitalaria y soporte vital básico en ahogados.

La nueva situación pandémica requeriría incluir todo el material de protección (EPI), sin embargo, la utilización en los entornos acuáticos puede ir de dificultoso a imposible.

El primer estudio con manta plástica pretendió analizar la viabilidad de su uso en la playa. Nuestra hipótesis es que la manta plástica es un método alternativo de protección que no afecta a la calidad de la RCP, además de permitir una colocación rápida sin demorar el inicio de las ventilaciones. Otras ventajas son el bajo coste y la facilidad de uso, algo necesario para profesionales que no tienen un entrenamiento específico ni usan a diario EPI para la reanimación.

Nuestro diseño consistió en un plástico transparente de 250 cm de largo por 150 cm de ancho, en una parte se pre-ensambló una a una máscara facial (pocket mask) con un filtro HEPA. El kit lo componen de 4 a 6 piquetas. Este plástico integrado en el maletín de primeros auxilios permite cubrir la víctima y comenzar las ventilaciones en 82s de media. En nuestro estudio, la calidad de RCP no se vio afectada, con un valor del 91% en 10 min. Otro aspecto relevante fue que una gran parte de los socorristas consideraron que usar este kit plástico era simple, en comparación con usar EPI completo (con bata impermeable).

Este sistema de manta de plástico, tiene una especial importancia a bordo de una embarcación de rescate. Bajo esta premisa comparamos tres set de EPIs en un bote semirrígido de socorristas, navegando a 20km/h, comparando nuevamente la Q-RCP, y analizando el tiempo de preparación del kit hasta el inicio de la primera ventilación.

El primer hallazgo importante, fue que el tiempo hasta la primera ventilación fue de 17s con nivel de protección básica, 34s con

protección basada en manta plástica y 69s con el EPI completo. Es decir, vestir EPI completo lleva 30s más, además el 43% de los socorristas, lo usaron mal o su colocación fue incorrecta, con amplias zonas corporales expuestas. En el test de reanimación no hubo diferencias significativas con ninguno de los tres sets y los valores fueron alrededor del 90% de Q-CPR.

*Implicaciones prácticas de los estudios*

Esta tesis ha pretendido aportar claves para resolver numerosas situaciones prácticas en un entorno especial y con eventos difícilmente comparables a otros entornos clínicos. Nuestros estudios se han centrado en los rescatadores (legos y profesionales) y deben servir para:

***Rescatadores legos:***

- Establecer campañas de prevención adecuadas para cada tipo de rescatador lego.
- Promover el entrenamiento de habilidades de rescate desde fuera del agua y auto-rescate para los rescatadores legos con mayor riesgo.
- Promover entrenamiento de habilidades de rescate y reanimación para rescatadores legos que por sus características, tienen la experiencia, el entrenamiento y la fortuna de encontrarse en el agua cuando realizan el rescate (surfistas).

***Socorristas profesionales:***

- Implementar nuevas posibilidades para iniciar la reanimación cuanto antes, especialmente proveer ventilaciones desde el primer momento de la parada respiratoria durante el ahogamiento.
- Mejorar las condiciones físicas de los socorristas, con la finalidad de que puedan recuperarse lo más rápido posible.
- Ofrecer recomendaciones y protocolos de reanimación para tratar el ahogamiento, analizando los diferentes medios de auto-protección basados en las características del entorno acuático.

## CONCLUSIONES

A continuación se presentan las conclusiones de esta tesis doctoral.

### Conclusiones de la H1

Existen diferentes perfiles de rescatadores legos, con variabilidad en sus capacidades y diferentes riesgos durante sus intentos de rescate. De forma genérica los testigos no debe entrar en el agua, sin embargo, los rescatadores legos con conocimiento y gran experiencia acuática que están dentro del agua pueden ser un gran activo en la mitigación del ahogamiento. No existe descripción de técnicas específicas para el rescate dentro del agua en legos, más allá de que los surfistas pueden usar su tabla como ayuda. Fuera del agua no hay reportes de cuánta

gente ha sido rescatada por lanzamientos de material de flotación, en cambio, existen numerosas evidencias de personas ahogadas intentando rescatar a otras víctimas.

**Conclusiones de la H2**

Iniciar la reanimación del ahogado de forma precoz es posible, tanto en MAR como en IRB, adaptando las técnicas conocidas al espacio disponible, posición del rescatador y condiciones marítimas. En MAR la calidad de las ventilaciones y las compresiones es aceptable. La experiencia del socorrista es un factor determinante para una buena aplicación de la RCP.

La protección (EPI) en tiempos de COVID-19 es posible, especialmente usando una manta de plástico. El uso de mantas plásticas ha sido testado con éxito tanto en tierra como navegando en una embarcación de rescate semi-rigida, no ha influido en la calidad de la RCP y ha recortado el tiempo en el inicio de las maniobras.

**Conclusiones de la H3**

Los métodos de recuperación activos promueven un reajuste fisiológico más rápido. La ES puede ser una alternativa de recuperación tras un rescate permitiendo al socorrista continuar con su trabajo de vigilancia.

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## INTRODUCIÓN

O afogamento é un problema importante de saúde pública e é responsable directo de case 300.000 mortes anuais en todo o mundo. Afecta especialmente a nenos e ten un especial impacto nos países de baixos ou medios recursos. A nivel global representa a terceira causa de morte por dano non intencional e supón o 7% de todas as mortes relacionadas con lesións.

En España estímase que 400 persoas falecen por afogamento cada ano. O afogamento defínese como *"o proceso polo que se experimenta unha imposibilidade para respirar por sumersión ou inmersión nun fluído"*, e de forma xenérica, o seu resultado pode ser a morte ou supervivencia con ou sen morbilidade. Considérase que o afogamento está infravalorado e a miúdo referiuse a *a "Metáfora do Iceberg"*. Un exemplo desta metáfora reflíctese nos datos comparativos; por cada persoa afogada que requiriu de atención médica, outras seis tiveron que ser rescatadas.

A prevención é a estratexia máis importante e a máis efectiva no balance custo/beneficio, por iso numerosas publicacións recomendan focar os

esforzos nas tarefas preventivas do afogamento, con todo, os datos epidemiolóxicos indican que aínda queda un longo camiño cara a unha prevención o suficientemente efectiva. É necesario estudar, entender e comprender os mecanismos desencadenantes, os perfís dos afogados e as habilidades e estratexias dos socorristas profesionais para atender ás persoas que sofren un incidente no medio acuático.

As circunstancias que envolven ao afogamento a miúdo adoitan ser multifactoriales, pero xenéricamente teñen que ver coa omisión das medidas de prevención ou asumir condutas de risco. Aínda así, o proceso de afogamento é silencioso, sutil e aínda non está suficientemente estudado, de aí a importancia da investigación en todos os aspectos do afogamento. Neste punto, coñecer como os rescatadores (legos ou profesionais) afrontan un incidente acuático, debe ser un dos retos da ciencia do afogamento.

Unha testemuña que presencia un afogamento e decide prestar auxilio é o que coñecemos como "rescatador lego" e defínese como a persoa que sen ser profesional ou ter un coñecemento específico intenta un rescate acuático. Poden existir diferentes tipos de rescatadoré legos en función do seu coñecemento e competencias.

En cambio, os socorristas son persoas que completaron un adestramento formal e son competentes para previr incidentes, rescatar e aplicar primeiros auxilios en contornas acuáticas.

Tanto testemuñas como profesionais son parte da solución, xa que tras avaliar as capacidades e limitacións de cada perfil, e propoñer as mellores prácticas para afrontar o rescate acuático, foi a orixe desta tese de doutoramento. Estes propósitos víronse alterados e modificados coa nova situación de saúde. No ano 2019 prodúcese unha das maiores alertas epidemiolóxicas dos últimos cen anos. O Acute *Respiratory Syndrome Coronavirus-2* (SARS-CoV-2). O mundo viviría en Europa o primeiro verán da Era COVID en 2020. A problemática para os socorristas é que as súas intervencións raramente danse noutros contextos médicos, e neste momento aínda complicouse máis pola COVID-19.

Esta tese pretende compilar as características, condicións e efectos das habilidades dos socorristas (legos ou profesionais) e mostrar as novas achegas adaptadas a tempos de COVID-19.

**HIPÓTESE**

H1. Os rescatadores legos teñen características, motivaciones e habilidades específicas que poden ser identificadas na literatura científica.

H2. As técnicas para a reanimación en caso de afogamento poden ser adaptadas e optimizadas para situacións aínda máis especiais (en embarcación de rescate ou con uso de Equipos de Protección Individual (EPI) durante Era COVID-19).

H3. A recuperación fisiolóxica do socorrista tralo rescate acuático pode acurtarse con estratexias utilizadas no deporte profesional.

## OBXECTIVOS

O1. Identificar os diferentes perfís rescatadores legos descritos na literatura científica.

O1.1. Clasificar as diferentes técnicas realizadas por rescatadores legos.

O1.2. Identificar o perfil e competencia dos rescatadores legos.

O2. Avaliar as habilidades dos rescatadores en diferentes contextos e situacións da reanimación en afogamento.

O2.1. Avaliar a viabilidad e calidade da reanimación en Moto Acuática de Rescate (MAR).

O2.2. Analizar as habilidades de reanimación con EPI.

Ou2.3. Comparar diferentes sets de EPI durante a reanimación a bordo dunha embarcación.

O3. Analizar estratexias de recuperación fisiolóxica trala intervención do socorrista.

O3.1. Analizar a recuperación pasiva tras un rescate acuático.

O3.2. Comparar o efecto da electro-estimulación (ES) sobre a recuperación tralo rescate acuático.

## METODOLOXÍA

Esta tese doutoral está composta de 6 publicacións que seguiron diferentes metodoloxías, adaptadas aos obxectivos establecidos en cada subestudo. O conxunto de artigos e o ámbito do socorrismo que abarca, pode apreciarse na *figura 1b.*

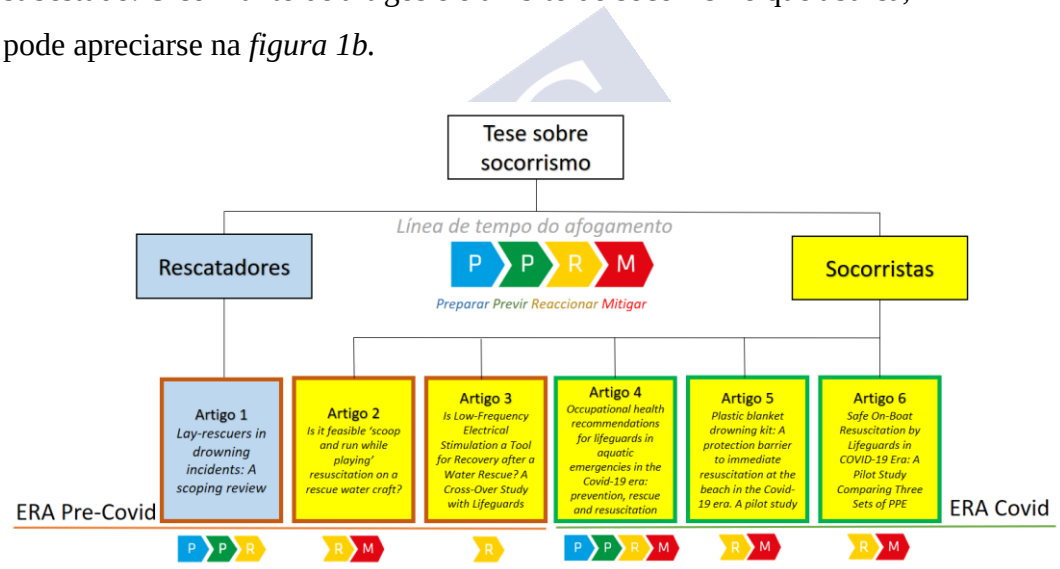


Figura 1b. Diagrama de fluxo do contido da Tese. Avaliación das habilidades dos rescatadores nos incidentes acuáticos.

Dous dos artigos son revisións, baseados en evidencias e propoñendo unha síntese dos resultados. O estudo titulado *"Lay-rescuers in drowning incidents: A scoping review"* é unha revisión sistemática da literatura seguindo a metodoloxía PRISMA. O estudo titulado

*"Occupational health recommendations for socorristas in aquatic emergencies in the Covid-19 era: prevention, rescue and resuscitation"* preséntase en forma de recomendacións baseadas en evidencias. A metodoloxía para realizar este artigo tamén seguiu unha metodoloxía PRISMA, pero a forma de presentar o manuscrito, pola propia finalidade do contido, segue a estrutura de recomendación científica.

Os catro restantes estudos *"Is it feasible 'scoop and run while playing' resuscitation on a rescue water craft? A randomized simulation study with socorristas"*, *"Plastic blanket drowning kit: A protection barrier to immediate resuscitation at the beach in the Covid-19 era. A pilot study"*, *"Safe on boat resuscitation by lifeguards in Covid-19 Era. A pilot study comparing three sets of protective persoal equipment"*, *"Is low-frequency Electrical Stimulation a tool for recovery after a Water Rescue? A Cross-Over Study with lifeguards"*, seguen unha metodoloxía cuasi-experimental. Son estudos cuantitativos, aleatorizados e transversales. A análise dos datos foi realizado co software estatístico SPSS (IBM Corp., Chicago, IL, USA). Mediante comparacións por pares (probas paramétricas –*TTest/Anova*- ou non paramétricas –*Wicolxon test*-) de dous ou máis factores. Os estudos presentan medias, desviacións típicas, intervalos de confianza (95%), frecuencias e tamaño do efecto. Estableceuse un nivel de significatividad de $p<0.05$ para todas as análises.

## RESULTADOS DAS PUBLICACIÓNS

**Artigo 1.** Lay-rescuers in drowning incidents: a scoping review.

[Rescatadores legos en incidentes acuáticos: unha revisión da literatura]

**Obxectivo.** Moitas vítimas de incidentes acuáticos son legos que tratan de rescatar a outro. Esta revisión ten como obxectivo identificar as técnicas e materiais máis seguros (improvisados ou deseñados específicamente) para que unha testemuña non capacitada úseos cando intente un rescate acuático.

**Método.** Unha mostra de 249 traballos foi incluída na procura bibliográfica, nos que finalmente seleccionáronse 19 seguindo a metodoloxía PRISMA e engadíronse 3 traballos presentados en congresos internacionais e revisados por pares. Incluíronse un total de 22 documentos á síntese cualitativa.

**Resultados**. A ubicación xeográfica, o nivel económico, a condición física ou a experiencia poden variar o perfil dos rescatadores legos e a forma de realizar un rescate acuático de xeito seguro. Identificáronse catro perfiles de rescatadores legos: 1) Nenos que rescatan a nenos en países con baixos e medios ingresos, 2) Adultos que rescatan a adultos ou nenos, 3) Testemuñas con algunha experiencia e adestramento en rescate, 4) Testemuñas con motivacións culturais ou profesionais. Tres tipos de técnicas utilizadas polos diferentes perfís de rescatadores legos: a) técnicas sen contacto para rescates desde terra: lanzamento e alcance,

b) técnicas sen contacto para rescate mediante material con flotación e, c) técnicas de rescate con contacto dentro da auga: nadar e remolcar con ou sen aletas.

**Conclusión**. A recomendación dos expertos é que a técnica máis segura para rescatadores legos é intentar un rescate usando unha rama, roupa ou algún material de flotación, sen entrar no auga. Con todo, aínda coa recomendación de rescates sen contacto dende terra, existe unha tendencia global a intentar rescates dende a auga, sen que ata o momento haxa evidencia de cal técnica ou procedemento pode contribuír a un rescate seguro. Deben considerarse estratexias de formación para legos.

**Artigo 2.** Is it feasible 'scoop and run while playing' resuscitation on a rescue water craft? a randomized simulation study with lifeguards.

[É posible rescatar e trasladar reanimando nunha moto de auga. un estudo aleatoriazado de simulación con socorristas]

**Obxectivo:** O tempo de resposta é un factor predictivo para a supervivencia das vítimas de afogamento. As motos acuáticas de rescate (MAR) son embarcacións moi habituais nas operacións de salvamento. O obxectivo deste estudo foi analizar a viabilidade de administrar ventilaciones boca a boca e / ou resucitación cardiopulmonar (RCP) efectivas en MAR mentres se navega a diferentes velocidades.

**Método:** Utilizouse un deseño cuasi-experimental cruzado para avaliar durante un minuto a viabilidade da ventilación Boca a Boca (BB) e a RCP tanto en terra (praia) como navegando a dúas velocidades diferentes 5 e 10 nós con mar en calma. As referencias de RCP de calidade (Q-RCP) foron as directrices do ERC de 2015.

**Resultados:** Incluíronse os datos de 13 socorristas que completaron 78 test de RCP . As habilidades de execución de só BB alcanzaron 69,7% ± 40,4 para 5 nós e 60,0% ± 41,8 para 10 nós (p = 0,59). Para a RCP estándar (compresións e ventilacións), o resultado foi 74,4% ± 24,2 e 68,5% ± 23,9 respectivamente. A calidade da BB e a RCP diminuíu non significativamente, mentres navegaba a 5 nós e 10 nós [(Q-BB; 5 nós: 59,9% ± 37,8 vs.10 nós: 43,2% ± 41,4, p = 0,42) (Q-RCP ; 5 nós: 64,8% ± 21,2 e 10 kn: 60,6% ± 21,0, p = 0,44)]. As variables de só BB e compresiones torácicas foron significativamente piores en MAR en comparación coa reanimación na praia (p <0,05). Observouse unha tendencia a mellores resultados por parte dos socorristas que se adestraron previamente en MAR .

**Conclusións:** As técnicas de reanimación a bordo de MAR son factibles e xa que logo poderían ser unha opción para os socorristas cando a súa formación, as condicións do mar, a distancia e as características da vítima permítano. As manobras de RCP poden ser moi efectivas a 10 nós, tanto para MM só como para RCP; con todo, a calidade das ventilaciones empeora drásticamente ao aumentar a velocidade.

**Artigo 3.** Is low-frequency electrical stimulation a tool for recovery after a water rescue? a cross-over study with lifeguards.

[É a electro-estimulación de baixa frecuencia unha ferramenta para a recuperación logo dun rescate acuático? un estudo cruzado con socorristas]

Este estudo tivo como obxectivo avaliar en que grado a electro-estimulación (ES) transcutánea mellorou a recuperación logo dun rescate acuático simulado. Neste estudo participaron vinte e seis socorristas. O rescate consistiu en nadar 100 m con aletas e tubo de rescate: 50 m de aproximación de nado e 50 m de remolque dunha vítima simulada. A concentracion de lactato en sangue, o esforzo percibido (RPE) e as propiedades contráctiles dos músculos se avaliaron ao comezo do estudo, despois do rescate na auga e despois do protocolo de recuperación pasiva (PR) ou activa con ES. A tensiomiografía, o RPE e os niveis basales de lactato en sangue indicaron equivalencia entre ambos grupos antes do rescate. Non houbo cambios na tensiomiografía antes e despois da recuperación e non houbo diferenzas entre os protocolos de recuperación (pasivo ou con ES). O RPE xeral, o RPE de pernas e o RPE de brazos logo de ES (media ± DE; 2,7 ± 1,53, 2,65 ± 1,66 e 2,30 ± 1,84, respectivamente) foron moderadamente máis baixos que logo de PR (3,57 ± 2,4, 3,71 ± 2,43 e 3,29 ± 1,79, respectivamente) ($p = 0,016$, $p = 0,010$, $p = 0,028$, respectivamente). Houbo un nivel de lactato en sangue significativamente máis baixo logo da recuperación con ES que en PR

(media ± DE; 4,77 ± 1,86 mmol • L-1 fronte a 6,27 ± 3,69 mmol • L-1; p = 0,045). A ES de baixa frecuencia inmediatamente tras o rescate na auga é unha estratexia de recuperación eficaz para eliminar a concentración de lactato en sangue.

**Artigo 4.** Occupational health recommendations for lifeguards in aquatic emergencies in the covid-19 era: prevention, rescue and resuscitation.

[Recomendaciones de saúde laboral para socorristas ante emerxencias acuáticas en era covid-19: prevención, rescate e reanimación]

A síndrome respiratoria aguda severa (SARS-CoV-2), que causa a enfermidade por coronavirus 2019 (Covid-19), é altamente contaxiosa. Os socorristas son a primeira liña de resposta nas emerxencias acuáticas e van sufrir unha forte exposición ao risco este primeiro verán de era Covid-19, polo que o seu saúde laboral debe ser reformulada na súa práctica profesional durante a nova normalidade. A principal medida de saúde pública para evitar afogamentos é a prevención, pero cando esta falla e requírese a asistencia ou o rescate, na maior parte das intervencións o distanciamiento non sexa posible. A limitación dos equipos de protección persoal (EPI) para o rescate é unha realidade que debe coñecerse e que pode afectar á saúde do socorrista. Realizouse unha revisión da literatura actual orientada a evitar ou minimizar o risco de contaxio nas intervencións realizadas por rescatadores en era Covid-19. Este artigo ofrece unha información estructurada sobre a prevención

do contaxio nos socorristas, os riscos potenciais, os EPI dispoñibles e as recomendaciones para o seu adecuado uso durante os rescates ou a atención prehospitalaria nas contornas acuáticas.

**Artigo 5.** Plastic blanket drowning kit: a protection barrier to immediate resuscitation at the beach in the Covid-19 era. A pilot study.

[kit de manta de plástico para afogamento: unha barreira de protección para a reanimación inmediata na praia durante era Covid-19. Un estudo piloto]

**Obxectivo:** Presentación dun novo equipamiento para socorristas simple e económico, composto por unha mascarilla facial pre-ensamblada a unha manta de plástico e a un filtro HEPA, o que pode ofrecer un significativo aforro de tempo e outras vantaxes para reducir o risco de transmisión do COVID-19 nos primeiros minutos da RCP tras un rescate acuático, eliminando o impacto negativo na demora da ventilación.

**Método:** Realizouse un estudo piloto para determinar a viabilidade do kit premontado de mascarilla e filtro HEPA adaptado sobre unha manta plástica. O primeiro paso consistiu en lavarse as mans, poñerse lentes e luvas de seguridade como primeiro equipo de protección persoal (EPI) e logo cubrir á vítima cunha manta plástica montada. O segundo paso consistiu en 10 min de reanimación cardiopulmonar (RCP) con EPI e

manta plástica, seguindo as recomendaciones técnicas para a ventilación durante o Covid-19.

**Resultados:** Dez socorristas participaron no estudo piloto. O tempo promedio para usar EPI e colocar o kit premontado sobre a vítima foi de 82 s [IC 58-105]. Logo de 10 min, a calidade da reanimación (Q-RCP) foi do 91% [87-94]. As calidade das compresións torácicas foi dun 22% mellores que as ventilacións. A maioría dos socorristas (60%) consideraron que colocar a manta de plástico sobre a vítima na praia era algo simple ou moi simple.

**Conclusións:** As técnicas de reanimación na praia durante era COVID-19 incrementaron a complexidade para o uso correcto de EPI. A manta plástica engade un plus para a ventilación o que podería ser unha nova alternativa a considerar polos socorristas para realizar ventilaciones mentres reducen o risco de transmisión.

**Artigo 6.** Safe on-boat resuscitation by lifeguards in Covid-19 era. a pilot study comparing three sets of protective persoal equipment.

[Reanimación segura a bordo realizada por socorristas en era Covid-19. un estudo piloto comparando tres sets de equipamiento persoal de protección]

**Introdución:** A reanimación a bordo pode ser aplicada por socorristas en embarcacións de rescate. A raíz da aparición do Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-COV-2) e as recomendacións para o uso de equipo de protección persoal (EPI), os

procedementos prehospitalarios foron reevaluados. O obxectivo deste estudo foi determinar como o uso de EPI inflúe no tempo de preparación necesario antes de comezar a reanimación (RCP) e na calidade da reanimación cardiopulmonar (Q-RCP) nunha embarcación de rescate semirríxida.

**Métodos:** Realizáronse tres probas de RCP con 14 socorristas, agrupados en parellas, con diferentes EPI: (1) EPI Básico (B-EPI): luvas, mascarilla e lentes protectoras; (2) EPI completo (F-EPI): B-EPI + un delantal impermeable; e (3) EPI básico + manta plástica (B + EPI). Realizouse unha RCP a bordo utilizando unha bolsa-válvula-máscara (BVM) e un filtro de aire de partículas de alta eficiencia (HEPA) navegando a 20 km / hora.

**Resultados:** o uso de B-EPI leva menos tempo e é significativamente máis rápido que o F-EPI (B-EPI 17 [SD = 2] segundos versus F-EPI 69 [SD = 17] segundos; P = 0,001), e o uso de B + EPI é lixeiramente superior (B-EPI 17 [SD = 2] segundos fronte a B + EPI 34 [SD = 6] segundos; P = 0,002). O QCPR mantívose similar nos tres escenarios (P>.05), alcanzando valores superiores ao 79%.

**Conclusión:** O uso de EPI durante a reanimación a bordo é factible e non interfere coa calidade cando é realizado por socorristas adestrados. O uso dunha manta de plástico podería ser unha alternativa rápida e fácil para ofrecer protección adicional aos socorristas durante a RCP nun bote de rescate.

## DISCUSIÓN

Esta tese realizada segundo a modalidade de compendio de publicacións tivo como principais obxectivos, analizar os perfís de rescatadores (tanto legos como socorristas), e afondar en diferentes estratexias educativas, fisiolóxicas e de reanimación, además de implementar condutas seguras mediante unha serie de recomendacións adaptadas a tempos de Covid-19.

Os seus principais achados foron:

d) Existen catro perfiles dominantes de rescatadores legos, con diferente risco en función da súa idade, procedencia, motivacións e experiencia.
e) O rescate acuático é fisiolóxicamente moi esixente. Supón gran demanda física e require xa que logo unha recuperación adecuada. Esta recuperación pode ser acelerada con métodos procedentes do deporte profesional (p.ex. foam roller/electro-estimulación).
f) O uso de mantas de plástico pode ser unha alternativa rápida e eficaz na RCP realizada por socorristas, tanto en terra como en embarcacións de rescate, sen demorar o inicio das ventilacións.

*Rescatadores legos, perfís e técnicas*

Para as testemuñas non profesionais, ata agora recomendouse que ante un incidente acuático non deben entrar na auga para intentar un rescate,

con todo esta recomendación entra en conflito con numerosas circunstancias; a) localización do incidente (a maioría entre os 50 e 100 m), b) relación de parentesco coa vítima e c) aspectos culturais por exemplo o caso dos surfistas australianos que contribúen notablemente aos salvamentos en praias non vixiadas. O consenso de expertos apoia que si é lego, só se recomenda o auxilio desde fóra da auga seguindo a secuencia "*reach, throw and don´t go* [alcanzar, lanzar e non ir]". Ainda así, a conduta humana máis repetida é intentar o rescate, o que en numerosas ocasións provoca o que se definiu como síndrome *Aquatic-Victim-Instead-of-Rescued*(AVIR) [vítima acuática en lugar de rescatador ], que consiste no intento de rescate dunha persoa que se está afogando, converténdose o rescatador tamén en vítima durante o intento. Ante esta conduta impulsiva e para mitigar as consecuencias dun rescate inexperto, algúns científicos australianos suxiren que todo bañista teña no seu material de praia *"tools for heroic acts"*[ferramentas para actos heroicos]. Este posicionamiento é ciertamente discutible, aínda que tamén moi realista. Para os rescatadores rescatadores legos(P) en que medida existen técnicas de rescate(I), en comparación con non intentar o rescate (C), e que non poña o risco nin expoña a un maior perigo ao rescatador(O)? É precisamente esta PICO *question* a que tratou de responder o primeiro artigo desta tese de doutoramento.

Atopáronse catro tipos de rescatadores legos. Para dous dos perfís: *1) Nenos rescatando nenos* e *2) Adultos rescatando adultos ou nenos*, é

posible que a educación xogue un papel fundamental para afrontar o risco coa maior seguridade posible. Ata agora as propostas científicas baseáronse na prevención do incidente, pero non hai referencias de como controlar os impulsos e tomar decisións correctas no momento do rescate.

A revisión mostra outros dous tipos de rescatadores legos con motivacións culturais, con experiencia ou con educación na seguridade do medio acuático como os surfistas, que contribúen notablemente aos rescates de bañistas en apuros, especialmente en praias non vixiadas.

*Socorristas profesionais; Rescate, reanimación e recuperación.*

Os socorristas son os profesionais encargados da prevención, vixilancia e intervención en caso de incidente acuático. O seu cometido é prover uns altos estándares en calidade asistencial, co obxectivo de evitar e/ou tratar calquera continxencia no medio acuático e a súa contorna.

Dentro deste campo da literatura, hai un estudo que ten un valor especial, xa que abordou por primeira vez a viabilidade para realizar a reanimación boca a boca a bordo dunha MAR.

Este estudo parte de dous conceptos vitais: gañar tempo e tratar a hipoxia, polo que se propón unha resposta a un debate clásico sobre o tratamento pre-hospitalario en situacións especiais de "*stay and play*" [tratar no sitio] or "*scoop and run*" [evacuar rápidamente].

A mellora de habilidades ten como base o adestramento, tanto técnico como físico, xa que o salvamento ten unha alta demanda fisiolóxica. Un achado común en todos os estudos sobre socorristas é a fatiga ocasionada polas súas intervencións. Isto ocorre tanto en embarcacións como especialmente tras rescates acuáticos a nado.

Os socorristas deben estar en boa forma física para afrontar os rescates, e a diferenza do salvamento deportivo, no socorrismo profesional tras realizar un rescate débese seguir traballando.

Un dos retos desta tese, foi analizar como se pode atenuar o efecto de fatiga aguda nos socorristas, buscando estratexias que axuden á súa recuperación sen que supoñan unha interrupción das súas labores profesionais. É neste momento, baseado nun equipo multidisciplinar de traballo con socorristas, médicos, enfermeiros, educadores físicos e fisioterapeutas, cando se suscita a electroestimulación para ser usada tralo rescate acuático.

Realizouse un estudo controlado colaborativo entre a Universidade de Vigo, a Universidade de Santiago de Compostela e a Universidade de Coimbra, na localidade do litoral portugués de Figueira dá Foz. Tras un rescate de 100m, aplicouse unha corrente de onda bifásica a 5 Hz, cunha duración de 0.25 milisegundos. O tempo de electroestimulación foi de 20min. A localización dos electrodos foi nos cuádriceps de ambas pernas, baseado en que os socorristas realizaron o rescate con aletas, e

a literatura científica mostra que durante a patada de crol con aletas, o músculo con maior implicación é o *rectus femoral*.

Os resultados obtidos, mostraron valores fisiolóxico a ter en conta. A electro estimulación reduciu significativamente a disminución da concentración de lactato e mostrou unha tendencia cara a unha menor fatiga percibida aínda que non logrou valores significativos ($p>0.05$).

*SARS-COV-2 e socorrismo*

Tralo confinamiento decretado polo Goberno de España, e mentres se empezou a dobregar a primeira onda, entramos en mayo/xuño, xusto o comezo da tempada de verán e ninguén pensara nos socorristas, nin no seu adestramento para afrontar o primeiro verán de Era COVID-19, nin no uso de EPI na praia, nin nas modificacións técnicas que requiren os procedementos de salvamento e reanimación do afogado.

Desde o grupo de traballo de socorrismo da Sociedade Española de Medicina de Urxencias (SEMES) xunto con outros investigadores do afogamento, creouse un grupo de traballo para promover unhas recomendacións de autoprotección e intervención para socorristas, que finalmente foi publicado en xuño do 2020 na Revista Española de Saúde Pública, do Ministerio de Sanidade.

Este grupo elaborou unha guía organizada en catro apartados: 1) Prevención do contaxio, cribado de positivos e riscos para o socorrista,

2) Equipo de protección individual (EPI). Posibilidades e limitacións, 3) Reacción ante o afogamento. Rescate acuático. 4) Mitigación: atención prehospitalaria e soporte vital básico en afogados.

A nova situación pandémica requiriría incluír todo o material de protección (EPI), con todo, a utilización nas contornas acuáticas pode ir de dificultoso a imposible.

O primeiro estudo con manta plástica pretendeu analizar a viabilidad do seu uso na praia. A nosa hipótese é que a manta plástica é un método alternativo de protección que non afecta á calidade da RCP, ademais de permitir unha colocación rápida sen demorar o inicio das ventilacións. Outras vantaxes son o baixo custo e a facilidade de uso, algo necesario para profesionais que non teñen un adestramento específico nin usan a diario EPI para a reanimación.

O noso deseño consistiu nun plástico transparente de 250 cm de longo por 150 cm de ancho, nunha parte pre-ensamblouse unha a unha máscara facial (pocket mask) cun filtro HEPA. O kit o está composto de 4 a 6 piquetas. Este plástico integrado no maletín de primeiros auxilios permite cubrir a vítima e comenzar as ventilaciones en 82s de media. No noso estudo, a calidade de RCP non se viu afectada, cun valor do 91% en 10 min. Outro aspecto relevante foi que unha gran parte dos socorristas consideraron que usar este kit plástico era simple, en comparación con usar EPI completo (con bata impermeable).

Este sistema de manta de plástico, ten unha especial importancia a bordo dunha embarcación de rescate. Baixo esta premisa comparamos tres sets de EPIs nun bote semirríxido de socorristas, navegando a 20km/h, comparando novamente a Q-RCP, e analizando o tempo de preparación do kit ata o inicio da primeira ventilación.

O primeiro achado importante, foi que o tempo ata a primeira ventilación foi de 17s con nivel de protección básica, 34s con protección baseada en manta plástica e 69s con EPI completo. É dicir, vestir EPI completo leva 30s máis, ademais o 43% dos socorristas, usárono mal ou o seu colocación foi incorrecta, con amplas zonas corporais expostas. No test de reanimación non houbo diferenzas significativas con ningún dos tres sets e os valores foron ao redor do 90% de Q-CPR.

*Implicacións prácticas dos estudos*

Esta tese pretendeu aportar claves para resolver numerosas situacións prácticas nunha contorna especial e con eventos difícilmente comparables a outras contornas clínicas. Os nosos estudos centráronse nos rescatadores (legos e profesionais) e deben servir para:

***Rescatadores legos:***

- Establecer campañas de prevención adecuadas para cada tipo de rescatador lego.

- Promover o adestramento de habilidades de rescate dende fóra da auga e auto-rescate para os rescatadores legos con maior risco.
- Promover adestramento de habilidades de rescate e reanimación para rescatadores legos que polas súas características, teñen a experiencia, o adestramento e a fortuna de atoparse no auga cando realizan o rescate (surfistas).

***Socorristas profesionais:***

- Implementar novas posibilidades para iniciar a reanimación canto antes, especialmente prover ventilacións desde o primeiro momento da parada respiratoria durante o afogamento.
- Mellorar as condicións físicas dos socorristas, coa finalidade de que poidan recuperarse o máis rápido posible.
- Ofrecer recomendaciones e protocolos de reanimación para tratar o afogamento, analizando os diferentes medios de auto-protección baseados nas características da contorna acuático.

## CONCLUSIÓNS

A continuación preséntanse as conclusións desta tese de doutoramento.

### Conclusións da H1

Existen diferentes perfís de rescatadores legos, con variabilidade nas súas capacidades e diferentes riscos durante os seus intentos de rescate. De forma xenérica as testemuñas non debe entrar na auga, con todo, os rescatadores legos con coñecemento e gran experiencia acuática que están xa dentro da auga poden ser un gran activo na mitigación do afogamento. Non existe descrición de técnicas específicas para o rescate dentro do auga en legos, máis aló de que os surfistas poden usar a súa táboa como axuda. Fóra do auga non hai reportes de canta xente foi rescatada por lanzamentos de material de flotación, en cambio, existen numerosas evidencias de persoas afogadas intentando rescatar a outras vítimas.

**Conclusións da H2**

Iniciar a reanimación do afogado de forma precoz é posible, tanto en MAR como en IRB, adaptando as técnicas coñecidas ao espazo dispoñible, posición do rescatador e condicións marítimas. En MAR a calidade das ventilacións e as compresións son aceptables. A experiencia do socorrista é un factor determinante para unha boa aplicación da RCP.

A protección (EPI) en tempos de COVID-19 é posible, especialmente usando unha manta de plástico. O uso de mantas plásticas foi testado con éxito tanto en terra como navegando nunha embarcación de rescate

semirríxida, non influíu na calidade da RCP e recortou o tempo no inicio das manobras.

**Conclusións da H3**

Os métodos de recuperación activos promoven un reaxuste fisiolóxico máis rápido. A ES pode ser unha alternativa de recuperación tras un rescate permitindo ao socorrista continuar co seu traballo de vixilancia.

# 1. INTRODUCTION

# 1. INTRODUCTION

Drowning is a major public health problem(1) and is directly responsible for almost 300,000 deaths annually worldwide (2). It particularly affects children and has an especially severe impact on low and middle-income countries (LMIC)(1). Globally, it is the third leading cause of unintentional injury death and accounts for 7% of all injury-related deaths (3).

In Spain, an estimated 400 people die from drowning each year (4). It should be noted that these statistics do not include migrants who die in Spanish waters. Drowning is defined as *"the process of experiencing respiratory impairment from submersion/immersion in liquid"*(5), and generically, its outcome may be death or survival with or without morbidity (5–7). Drowning is considered to be underrated and has often been referred to as the *"Iceberg Metaphor."*(8,9). An example of this metaphor is reflected in the comparative data; for every drowning person who required medical attention, six others had to be rescued (10).

Prevention is the most important strategy and the most effective in the cost/benefit balance, which is why numerous publications recommend focusing efforts on drowning prevention tasks. (4,10–14). However,

epidemiological data indicate that there is still a long way to go towards sufficiently effective prevention (2). It is therefore necessary to study, understand and comprehend the mechanisms that trigger this incident, the profiles of drowning victims and the skills and strategies of professional rescuers to care for the victims.

*The Drowning Chain of Survival* (11), is the first international consensus document that structured the phases of drowning in a logical time sequence. The main algorithm is composed of 5 links:

1. Prevention,

2-4. Sequence occurring in the water;

    2. Recognition of the victim,

    3. Provide flotation,

    4. Rescue (remove from water),

    5. Provide care as needed.

More recently, the so-called *Drowning Timeline* was published (12), and it is a systematic model that includes four groups of actions:

a. Prepare the community to prevent drowning

b. Prevent drowning actively or reactively

c. Reacting to the incident

d. Mitigate the effects of drowning in the post-event.

Drowning differs by gender, age and location. (1–3,6,14,15). Males, children and citizens of LMIC are at increased risk of drowning.

The triggers are often multifactorial (16), but in general they have to do with the omission of preventive measures or assuming risky behaviors. Prior to entering the water, triggers such as ignoring alerts or warnings about the state of the sea, alcohol consumption, lack of knowledge of the environment or low level of aquatic competence are triggers for drowning (6,17–20). In swimming pools, the absence of perimeter fences (*figure 1*) or continuous supervision is also strong triggers for drowning, especially in children. (17,21).

Figure 2. Prevention mechanism. Perimeter fence preventing free access to the pool (own photograph).

The second link in the chain of drowning survival is to recognize so-called "distress" (11). The term *aquatic stress/distress* includes the two

processes related to emotional control that can occur sequentially or in parallel. The recently published definition, which has an important consensus is that *"two processes that occur when a person feels at risk of drowning. Stress evokes the person to try to find ways to get out of the situation. If the ability to rationally cope with the stressful condition is overwhelmed, a distress situation follows*"(22).

The drowning process is silent, subtle and not yet sufficiently studied, hence the importance of research into all aspects of drowning (23). Avramidis et al. presented the 4 W-model in which videos of aquatic incidents were analyzed as well as the behaviors of people who were experiencing a drowning and this provided some of the drowning outcome, such as rescuer characteristics, location or type of incident. (24). The drowning process can last from a few seconds to a few minutes (6) and by means of recent video analysis, Carballo-Fazanes & Bierens produced a study which found that the average time in which a victim became unconscious in a drowning process was 92s and the disappearance under water was 106s.(23). At this time, submergence time is the key factor, with the association between shorter submergence time and rapid response by Emergency Medical Services (EMS) being a key factor for survival (25). The final part of dealing with drowning or minimizing its consequences is described in the *Drowning Timeline* as *mitigation* (12) and in the *Drowning Chain of Survival* it is in the last link; that is, providing the necessary care (11).

On this point, knowing how rescuers (lay or professional) deal with an aquatic incident should be one of the challenges of drowning science. A *Layperson* is a person without professional or specialized knowledge in a subject area (in this case aquatic rescue) and there may be varying levels of knowledge depending on a person´s background (22).

In contrast, *Lifeguards* are individuals who have completed training and have the necessary competence to prevent incidents, rescue and apply first aid in aquatic environments (22).

In relation to lay rescuers, identifying their profiles, motivations, location (whether in or out of the water) and the techniques they use will help us to establish prevention campaigns to prevent drowning and also deaths when trying to rescue another person, i.e. *aquatic victim-instead-of-rescuer syndrome* (AVIR)-(26). It will also help us to better understand how lay-rescuers with experience in the aquatic environment (e.g. surfers)(27) can contribute to water rescues. Surfers may fall into the category of lay-rescuer with water rescue training and a certain level of competence to perform a rescue (22).

In relation to professional lifeguards, analyzing their behavior and carrying out research with the aim of optimizing their performance should be a priority. This could greatly improve their capabilities and the effectiveness of their rescues. Nowadays, it is a fact that on beaches where lifeguards are present, the incidence of fatal drownings is indeed very low (6). However, the proportion of preventive or rescue

interventions is an important asset in the prevention of drowning (10). In the area of rescuers and their actions, research is still very limited. Some studies have addressed the effect of fatigue following rescue (28–34) or the different rescue materials used (30,31,35,36). Others have examined competence in sand resuscitation (29,30,30,31), in-water resuscitation (37–40), on-boat resuscitation(41–46), or even simulation studies and cohorts of real interventions have also been studied. Drowning is a time-dependent event, so every second counts. Lifeguards must not only be proficient in the water. The lifeguard is actually a hybrid between an athlete and a paramedic. Sports science and health science must work together to prevent drowning and mitigate its consequences. Lifeguards must be treated as sports professionals and be given all available resources to help them get there faster and recover sooner. In short, to be in the best condition to deal with an imminent rescue. In recent years, research on the performance of professional lifeguards has increased with the analysis of their physical capabilities (32,35,47,48) or the consequences of their interventions(49) and novel strategies for recovery after rescues(50). However, the physiological conditioning of the rescuer is a field which has still barely been explored in sport sciences.

Research is a living and oftentimes changing process, in which a new finding or a modification of reality can change any paradigm. This often happens in a period of years, but recently we have experienced it in a matter of months.

The year 2019 witnessed one of the biggest health alerts in the last hundred years. The Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), appeared for the first time in the city of Wuhan (China). This type of coronavirus is responsible for the disease called COVID-19 (51). The World Health Organization (WHO) granted this disease pandemic status on March 11, 2020 (52). This highly infective coronavirus spread via fomites and especially aerosols, meant that all protocols for EMS had to be rethought. In an accelerated sprint of science worldwide, changes were addressed from multiple sectors: virologists learning and providing more precise evidence every week, vaccine development in record time (the fastest vaccine in history) and strong research for self-protection during health care.

In Europe, the world experienced the first summer of the COVID era in 2020, following a large scale lockdown internationally. The problem for rescuers is that their interventions rarely occur in other medical contexts (53). In this regard, scientific societies related to drowning such as the *International Drowning Research Alliance* (IDRA) (54), the *International Life Saving Federation* (ILS)(54) through the medical commission, and the *Spanish Society of Emergency Medicine* (SEMES)(55) through the lifeguard working group, offered the first recommendations for lifeguards to meet the challenges of the new era.

At present, and with the end of the health emergency on the horizon thanks to vaccination, some protocols will return to their previous state but others will endure and should therefore be evaluated scientifically.

This thesis aims to compile the characteristics, conditions and effects of the skills of first responders (lay or professional) and to show the new contributions adapted to COVID-19 times. For this purpose, the narrative discourse of this thesis will follow each of the Drowning Timeline actions (pre-event, event and post-event). In Europe, the world will experience the first summer of the COVID era in 2020, following a generalized lockdown. The problem for rescuers is that their interventions rarely occur in other medical contexts (53). This thesis aims to compile the characteristics, conditions and effects of the skills of first responders (lay or professional) and to show the new contributions adapted to COVID-19 times.

For this purpose, the narrative discourse of this thesis will follow each of the *Drowning Timeline* actions (pre-event, event and post-event).

# 2. HYPOTHESIS & OBJETIVES

# 2. HYPOTHESIS & OBJETIVES

In this section the hypotheses and the research objectives are presented.

Our hypotheses and objectives aim to address different gaps around the drowning field. Drowning is one of a major public health problem worldwide. For this casualty prevention is the most important strategy and the most effective in the cost/benefit balance. However, epidemiological data indicate that there is still a long way to go in this sense. It is therefore necessary to study, understand and comprehend the mechanisms that trigger this incident, the profiles of drowning victims and the skills and strategies of professional rescuers to care for the victims. The triggers of drowning are often multifactorial, but in general they have to do with the omission of preventive measures or assuming risky behaviors. The drowning process is silent, subtle and not yet sufficiently studied, hence the importance of research into all aspects of drowning.

One relevant knowledge gap in this field is to know how rescuers, being laypeople or professionals wit the duty to assist, deal with an aquatic incident. About lay rescuers, identifying their profiles, motivations, location (whether in or out of the water) and the techniques they use will help us to establish prevention campaigns to prevent drowning and

also deaths when trying to rescue another person, i.e. *aquatic victim-instead-of-rescuer syndrome*. It will also help us to better understand how lay-rescuers with experience in the aquatic environment (e.g. surfers) can contribute to water rescues.

In relation to professional lifeguards, analyzing their behavior and carrying out research with the aim of optimizing their performance should be a priority, but in this field quality investigations and scientific evidences are very limited. Obtaining new and solid evidences could support evidence-based guidelines that could greatly improve their capabilities and the effectiveness of their rescues.

Drowning and cardiopulmonary resuscitation in case of drowning related cardiac arrest is a time-dependent event, so every second counts. The lifeguard is a hybrid between an athlete and a paramedic; therefore sports and health sciences must work together to prevent deaths and long-term disabilities. However, the physiological conditioning of the rescuer has barely been explored in controlled tests and trials.

In addition to the above commented drowning-related knowledge gaps, the current COVID-19 pandemics has challenged the way we deliver clinical care as well as assistance to drowning victims. The new situation demands new solutions and adaptations to maintain high quality water rescuers and resuscitations while protecting the health of lifeguards and other rescuers. However, practically nothing about the topic is know from the scientific point of view and new procedures and

devices should be designed and tested in simulated conditions before their recommendation if deemed effective or alternatively contraindicated otherwise.

Based on the above mentioned knowledge gaps and the expectations of the research team involved in the scientific studies compiled in the present doctoral thesis, the following hypothesis and objectives are enunciated:

## 2.1. HYPOTHESIS

**H1.** As lay-rescuers are involved in real drowning events and their profiles may be related to the victims' outcome, we hypothesize that lay-rescuers have specific characteristics, motivations and skills which can be identified in scientific literature.

**H2.** Usual rescue techniques are focused in standard victims and environments. The techniques for resuscitation in the case of drowning can be adapted and optimized for even more special situations (on rescue water craft or with use of Protective Protection Equipment (PPE) during the COVID-19 era).

**H3.** Training of rescuers must consider the effort's physiology. The physiological recovery of the rescuer after water rescue can be shortened by adopting strategies used in professional sport.

## 2.2 OBJECTIVES

In order to try to confirm or refute the above-mentioned hypothesis, the studies included in this doctoral thesis have been designed and perform with the following general and specific objectives. These objectives are reflected in more detail in the published articles that compose the compendium and include the profile of the rescuer, both lay and professional, the evaluation of resuscitation skills in special circumstances and the physiological profile of the water rescue.

**General Objective 1.** To review the currenty available evidences and reviews in order to identify the different lay-rescuer profiles described in scientific literature, by means of a PICO question and procedure methodology.

Specific objective 1.1. To obtain scientific evidences that may permit to classify the different techniques performed by lay-rescuers and to make solid guidelines and recommendations for improvement of drowning management.

Specific objective 1.2. To obtain solid scientific clues that may permit to identify the profile and competence of lay-rescuers in order to generate safe and efficient protocols.

**General Objective 2.** To assess in controlled research conditions the skills of rescuers in different real contexts and situations of drowning resuscitation.

Specific objective 2.1. To evaluate the feasibility of the procedure and the quality of maneuvers of Rescue Water Craft (RWC) resuscitation, that include the quality of chest compressions (rate, depth, hands position, decompression, chest compression fraction) and rescue ventilations.

Specific objective 2.2. To systematically analyze the resuscitation skills when the rescuers wear personal protective equipment (PPE) in controlled conditions that resemble the real situation of a victim placed on the sand in pandemic conditions with risk of contagion by airborne pathogens.

Specific objective 2.3. In order to obtain evidences that could support guidelines to recommend which kind of protection equipment should be used in each specific environments the objective of this subset of the research is to compare the results of using different PPE sets during on-boat CPR.

**General Objective 3.** Considering that a relevant scientific question in the resuscitation and lifesaving field is to know how to minimize the fatigue during rescue (water rescue and first aid) and the potential impact of the recovery once the lifeguard is already fatigued the objective is to analyze the physiological recovery strategies after rescuer intervention.

Specific objective 3.1. To analyze the rescuers' physical passive recovery after a water rescue

Specific objective 3.2. Considering that electrostimulation is a technique that has been tested in several conditions and environments and its potential for lifeguards recovery this objective is to assess in controlled conditions the physiological positive effects of electrostimulation (ES) on recovery after aquatic rescue.

# 3. METHODOLOGY

# 3. METHODOLOGY

## 3.1 General Methodological Description

This doctoral thesis is composed of 6 publications that have followed different methodologies, adapted to the objectives established in each sub-study. The set of articles and the scope of lifeguarding covered can be seen in *Figure 2.*

Two of the articles are narrative, evidence-based and propose a synthesis of the results. The study entitled *"Lay-rescuers in drowning incidents: A scoping review"*(14) is a systematic review of the literature following PRISMA methodology (56). The initial literature review was provided by a librarian from the Belgian Red Cross Reference Center and checked by a drowning expert (Linda Quan). Following the systematic review procedure, two authors (Roberto Barcala-Furelos and Daniel Grahan) analyzed the literature separately, coincidentally including a total of 22 papers. The qualitative analysis performed by RBF and DG was reviewed by another pair of co-authors (Cristian Abelairas-Gómez and Antonio Rodríguez-Núñez).

The study entitled *"Occupational health recommendations for lifeguards in aquatic emergencies in the Covid-19 era: prevention, rescue and resuscitation"*(55) is presented in the form of evidence-based guidelines. The methodology for this paper also followed a PRISMA (56) methodology, but the way of presenting the manuscript, due to its practical purpose and the novelty of the content, follows the structure of a scientific recommendation.

The remaining four studies, *"Is 'scoop and run while playing' resuscitation feasible on a rescue water craft? A randomized simulation study with lifeguards"*(57), *"Plastic blanket drowning kit: A protection barrier to immediate resuscitation at the beach in the Covid-19 era. A pilot study"*(58), *"Safe on-boat resuscitation by lifeguards in Covid-19 Era. A pilot study comparing three sets of protective personal equipment"*(44), *"Is low-frequency Electrical Stimulation a tool for recovery after a Water Rescue? A Cross-Over Study with Lifeguards"*(59), followed a quasi-experimental methodology. They are quantitative, randomized, cross-sectional studies. Data analysis was performed with SPSS statistical software (IBM Corp., Chicago, IL, USA) by means of pairwise comparisons (parametric tests -Test/Anova, or the non-parametric Wilcoxon test) of two or more factors. The studies present mean, standard deviation, confidence intervals (95%), frequencies and effect size. A significance level of $p<0.05$ was established for all analyses.

### 3.2 STUDY VARIABLES

The set of dependent variables generically encompassed the following variables:

1) Quality of CPR reported using the Little Anne QCPR manikin software (Laerdal, Norway). Recording partial variables of chest compression (CC): Rate, Depth and Chest Recoil. Ventilations (V): V with effective air intake and V with adequate volume. The programming parameters were under the 2015 European Resuscitation Council Guidelines for Resuscitation (ERCG2015) (60).

2) Time of skills: Rescue time or time to intervention. It was measured in seconds (s).

3) Physiological parameters: Rating of Perceived Effort (RPE) according to Borg's Scale (61,62). Blood lactate (BL) measured in millimoles/liter (mmol/l) of lactic acid, recorded with LactateScout device (SensLab GmbH, Leipzig, Germany). Maximal radial muscle-belly displacement (Dm) and Contraction time (CT) recorded with Tensiomyography (TMG-S1).

### 3.3 ETHICAL ASPECTS

All the work has respected the ethical principles of the Declaration of Helsinki and has been authorized by an ethics committee. The data was anonymized and complied with current legislation on data protection.

Those experimental studies that required an ethics committee were included in the scientific publication.

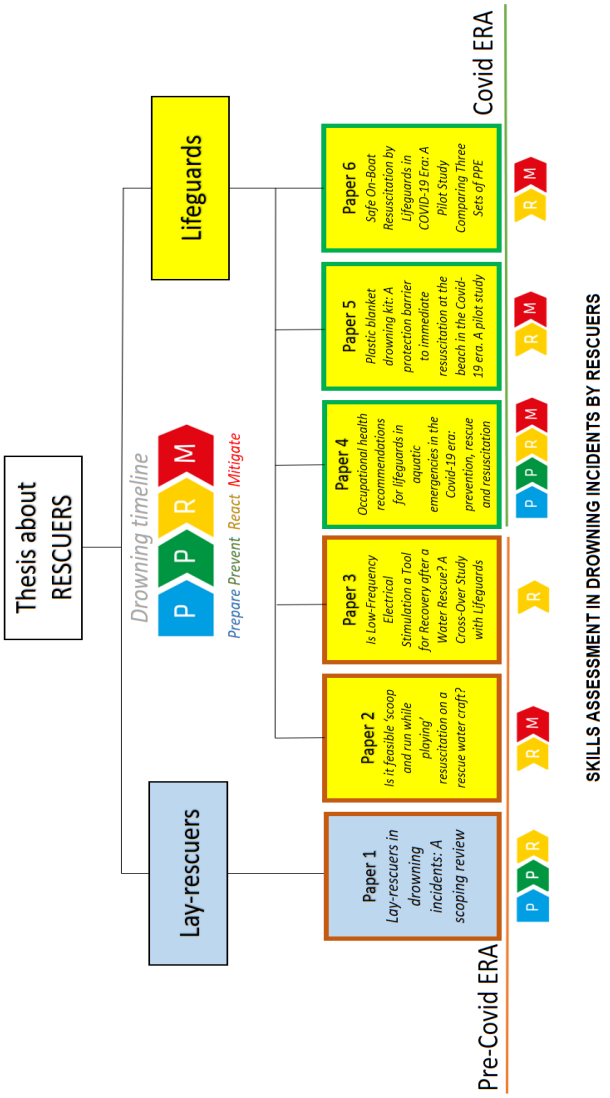


Figure 1b. Flow chart of Thesis content: Skills assessment in drowning incidents by rescuers

# 4. RESULTS OF PUBLICATIONS

# 4. RESULTS OF PUBLICATIONS

## 4.1. ARTICLE 1. LAY-RESCUERS IN DROWNING INCIDENTS: A SCOPING REVIEW

The American Journal of Emergency Medicine
Volume 44, June 2021, Pages 38-44

Lay-rescuers in drowning incidents: A scoping review

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Received 24 December 2020, Revised 24 January 2021, Accepted 25 January 2021, Available online 31 January 2021.

Figure 3. Screenshot of the article identification, available at https://www.sciencedirect.com/science/article/pii/S0735675721000723?via%3Dihub.

### 4.1.1 Evidence of Quality

This article published in the *The American Journal of Emergency Medicine* has an impact factor of 1.911 in the Journal Citation Report (JCR).

- Category: Science Edition - EMERGENCY MEDICINE
- Indexed in JRC: Quartile 2 (Q2) and in SJR (Q1).
- Repositories: Web of Science and Scopus.
- This journal is a reference in the field of pre-hospital medicine and emergency triggers.

Full citation of the manuscript

Barcala-Furelos R, Graham D, Abelairas-Gómez C, Rodríguez-Núñez A. *Lay-rescuers in drowning incidents: A scoping review.* Am J Emerg Med. 2021 Jan 31;44:38-44. doi: 10.1016/j.ajem.2021.01.069. Epub ahead of print. PMID: 33578330.

Publication contribution.

Leadership in writing the manuscript (first author). Being one of the peers in the literature analysis in the review. Elaboration of the qualitative analysis. Preparation of tables and conceptualization of figures. Submission of the manuscript and resubmission of the revised version.

### 4.1.2 Article abstract

**Objective**. Many victims of drowning fatalities are lay-people attempting to rescue another person. This review aims to identify the

safest techniques and equipment (improved or purpose made) for an untrained bystander to use when attempting a water rescue.

**Method**. A sample of 249 papers were included after the bibliographic search, in which 19 were finally selected following PRISMA methodology and 3 peer review proceedings presented at international conferences. A total of 22 documents were added to the qualitative synthesis.

**Results**. Geographical location, economic level, physical fitness, or experience may vary the profile of the lay-rescuers and how to safely perform a water rescue. Four lay-rescuers profiles were identified:

1) Children rescuing children in low- and middle-income countries (LMICs) 2) Adults rescuing adults or children

3) Lay-people with some level of experience and rescue training

4) Lay-people with cultural or professional motivations.

There are three types of techniques used by those lay-rescuers profiles:

a) Non-contact techniques for rescues from land: i.e. throw and reach

b) Non-contact techniques for rescue using a flotation device

c) Contact techniques for rescue in the water: swim and tow with or without fins.

**Conclusion**. The expert recommendation of the safest technique for a lay-rescuer is to attempt rescue using a pole, rope, or flotation equipment without entering the water. However, despite the recommendations of non-contact rescues from land, there is an overall tendency to attempt contact rescues in the water, despite a lack of evidence on which technique, procedure or equipment contributes to a safer rescue. Training strategies for lay-people should be considered.

Highlights:

1) The safest technique for a lay-rescuer is to attempt rescue from the land or a boat, throwing a pole, rope, or flotation equipment without entering the water.

2) Four different lay-rescuer profiles were found. Prevention strategies should be adjusted to target each profile.

3) If lay-rescuers are already in the water when the incident occurs (e.g., surfers), and they have good knowledge of the aquatic environment, experience in water rescue skills, good physical fitness, and floatation equipment, they could consider attempting a rescue only if it's safe.

## 4.2. ARTICLE 2. IS IT 'SCOOP AND RUN WHILE PLAYING' RESUSCITATION FEASIBLE ON A RESCUE WATER CRAFT? A RANDOMIZED SIMULATION STUDY WITH LIFEGUARDS

The American Journal of Emergency Medicine
Volume 38, Issue 3, March 2020, Pages 618-623

Brief Report

Is it feasible "scoop and run while playing" resuscitation on a rescue water craft? A randomized simulation study with lifeguards

Roberto Barcala-Furelos [a, b], Cristian Abelairas-Gomez [b, c], Silvia Aranda-García [d], Miguel Lorenzo-Martínez [a], Santiago Martínez-Isasi [b], Carlota Durán-Álvarez [e], José Palacios-Aguilar [f], Antonio Rodríguez-Núñez [b]

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Received 7 September 2019, Revised 28 October 2019, Accepted 31 October 2019, Available online 18 November 2019.

Figure 4. Screenshot of the article identification, available at https://www.sciencedirect.com/science/article/pii/S0735675719307387

### 4.2.1 Evidence of Quality

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- Indexed in JRC: Quartile 2 (Q2) and in SJR (Q1).

- Repositories: Web of Science and Scopus.
- This journal is a reference in the field of pre-hospital medicine and emergency triggers.
- JCR Cites: 3. PlumX Metrics: Mendeley 23, twitter 33.

Full citation of the manuscript

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Publication contribution

Leadership in writing the manuscript (first author). Development of the idea. Data collection processing. Preparation of tables and conceptualization of figures. Submission of the manuscript and resubmission of the revised version.

### 4.2.2 Article abstract

**Objective:** Response time is a predictive factor for the survival of drowning victims and lifesaving. Rescue Water Craft (RWC) are very common lifeboats in lifeguards operations. The aim of this study was

to analyze the feasibility of providing effective mouth-to-mouth ventilations and/or cardiopulmonary resuscitation (CPR) on the RWC while sailing at different speeds.

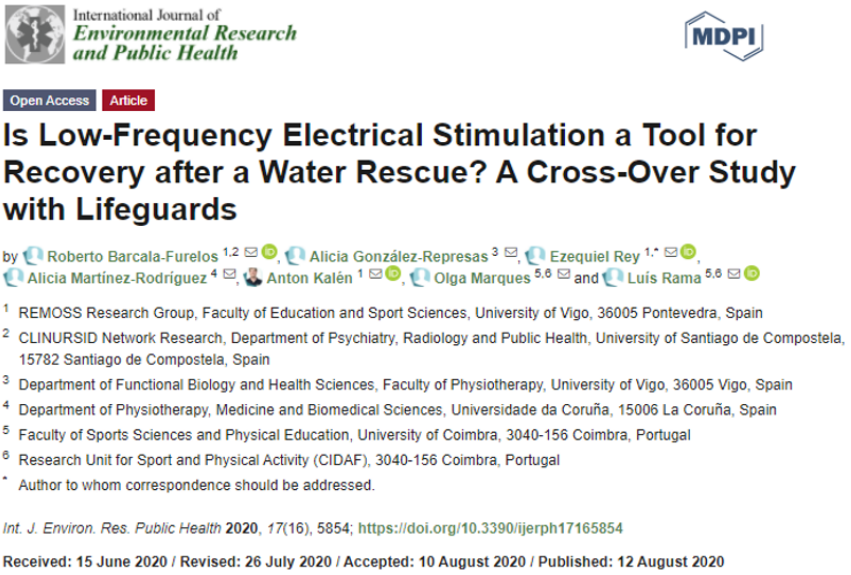
**Method:** A quasi-experimental cross-over block design was used to test the effectiveness of Mouth to Mouth ventilation during one minute efforts (MM-only) and CRP, at the beach and sailing at two different speeds 5 knots(kn) and 10 kn with a calm sea. The Quality CPR (Q-CPR) reference were the 2015 ERC guidelines.

**Results:** The data obtained from 13 lifeguards were included, which means that 78 resuscitation tests were completed. The MM-only performance skills reached 69.7% ± 40.4 for 5 kn and 60.0% ± 41.8 for 10 kn ($p = .59$). For full CPR, performance was 74.4% ± 24.2 and 68.5% ± 23.9 respectively. Quality of MM and CPR decreased, albeit not significantly, while sailing at 5 kn and 10 kn [(Q-MM; 5 kn: 59.9% ± 37.8 vs. 10 kn: 43.2% ± 41.4, $p = .42$)(Q-CPR; 5 kn: 64.8% ± 21.2 and 10 kn: 60.6% ± 21.0, $p = .44$)]. MM-only and CC variables were significantly worse on RWC when compared with resuscitation at the beach ($p < .05$). A trend for better results by lifeguards previously training on RJS was observed.

**Conclusions:** Resuscitation techniques on board a RWC are feasible and therefore they could be an option for lifeguards when their training, sea conditions, distance and the victim's characteristics allow it. CPR maneuvers may be highly effective at 10 kn, both for MM-only and

CPR. However, the quality of the ventilations dramatically worsen with increasing speed.

## 4.3. ARTICLE 3. IS LOW-FREQUENCY ELECTRICAL STIMULATION A TOOL FOR RECOVERY AFTER A WATER RESCUE? A CROSS-OVER STUDY WITH LIFEGUARDS



International Journal of *Environmental Research and Public Health*

MDPI

Open Access Article

**Is Low-Frequency Electrical Stimulation a Tool for Recovery after a Water Rescue? A Cross-Over Study with Lifeguards**

by Roberto Barcala-Furelos [1,2], Alicia González-Represas [3], Ezequiel Rey [1,*], Alicia Martínez-Rodríguez [4], Anton Kalén [1], Olga Marques [5,6] and Luís Rama [5,6]

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Figure 5. Screenshot of the article identification, available at https://www.mdpi.com/1660-4601/17/16/5854

### 4.3.1 Evidence of Quality

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Contribution to the publication

Leadership in writing the manuscript (first author). Development of the idea. Obtaining results (Data). Preparation of tables and conceptualization of figures. Submission of the manuscript and resubmission of the revised version.

### 4.3.2 Article abstract

This study aimed to evaluate the degree to which transcutaneous electrical stimulation (ES) enhanced recovery following a simulated water rescue. Twenty-six lifeguards participated in this study. The

rescue consisted of swimming 100m with fins and a rescue-tube: a 50m swim approach and a 50m tow-in with a simulated victim. Blood lactate clearance, rated perceived effort (RPE), and muscle contractile properties were evaluated at baseline, after the water rescue, and after ES or passive-recovery control condition (PR) protocol. Tensiomiography, RPE, and blood lactate basal levels indicated equivalence between both groups. There was no change in tensiomiography from pre to post-recovery and no difference between recovery protocols. Overall-RPE, legs-RPE and arms-RPE after ES (mean ± SD; 2.7 ± 1.53, 2.65 ± 1.66, and 2.30 ± 1.84, respectively) were moderately lower than after PR (3.57 ± 2.4, 3.71 ± 2.43, and 3.29 ± 1.79, respectively) ($p = 0.016$, $p = 0.010$, $p = 0.028$, respectively). There was a significantly lower blood lactate level after recovery in ES than in PR (mean ± SD; 4.77 ± 1.86 mmol·L−1 vs. 6.27 ± 3.69 mmol·L−1; $p = 0.045$). Low-frequency ES immediately after a water rescue is an effective recovery strategy to clear out blood lactate concentration.

## 4.4. ARTICLE 4. OCCUPATIONAL HEALTH RECOMMENDATIONS FOR LIFEGUARDS IN AQUATIC EMERGENCIES IN THE COVID-19 ERA: PREVENTION, RESCUE AND RESUSCITATION

Rev Esp Salud Pública. 2020; Vol. 94: June 30th. e1-16. www.mscbs.es/resp

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OCCUPATIONAL HEALTH RECOMMENDATIONS FOR LIFEGUARDS IN AQUATIC EMERGENCIES IN THE COVID-19 ERA: PREVENTION, RESCUE AND RESUSCITATION

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Authors declare that there is no conflict of interest.

Figure 6. Screenshot of item identification, available at https://www.mscbs.gob.es/biblioPublic/publicaciones/recursos_propios/resp/revista_cdrom/VOL94/C_ESPECIALES/RS94C_202006074.pdf.

### 4.4.1 Evidence of Quality

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Contribution to the publication

Leadership in writing the manuscript (first author). Development of the idea. Elaboration of tables and conceptualization of figures. Elaboration of the manuscript. Submission of the manuscript and resubmission of the revised version.

### 4.4.2 Article abstract

Severe acute respiratory syndrome (SARS-CoV-2), which causes coronavirus disease 2019 (COVID-19), is highly contagious. Lifeguards are the first line of response in aquatic emergencies and they were seriously exposed to risk during the first summer of the Covid-19

era, so their occupational health must be rethought in their professional practice during the new normal. The main public health measure to prevent drowning is actual prevention, but when this fails and assistance or rescue is required, in most interventions, distancing will not be possible. The limitation of personal protective equipment (PPE) for rescue is a reality that must be known and it can seriously affect the health of the lifeguard. A review of the current literature aimed at avoiding or minimizing the risk of contagion in the interventions carried out by rescuers in the Covid-19 era was performed. This article provides structured information on the prevention of contagion in lifeguards, the potential risks, the available PPE, and the recommendations for its proper use during rescue or prehospital care in aquatic settings.

## 4.5. ARTICLE 5. PLASTIC BLANKET DROWNING KIT: A PROTECTION BARRIER TO IMMEDIATE RESUSCITATION AT THE BEACH IN THE COVID-19 ERA. A PILOT STUDY

The American Journal of Emergency Medicine
Volume 38, Issue 11, November 2020, Pages 2395-2399

Plastic blanket drowning kit: A protection barrier to immediate resuscitation at the beach in the Covid-19 era. A pilot study.

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Figure 7. Screenshot of item identification, available at https://www.sciencedirect.com/science/article/pii/S0735675720307695.

### 4.5.1 Evidence of Quality

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- Category: Science Edition - EMERGENCY MEDICINE
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- Repositories: Wos of Science and Scopus.

Full manuscript citation

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Publication contribution.

Leadership in writing the manuscript (first author). Co-conception of the idea together with Antoni Rodríguez-Núñez. Data collection processing. Elaboration of tables and conceptualization of figures. Elaboration of the final version of the manuscript and the revised version.

### 4.5.2 Article abstract

**Objective:** Introducing a new, simple and inexpensive type of portable equipment for lifeguards, consisting of a pre-assembled full-size plastic blanket with a mask and HEPA filter, which could offer significant time-saving advantages to reduce COVID-19 risk transmission in the first few minutes of CPR after water rescue, thus avoiding the negative impact of delayed ventilation.

**Method:** A pilot study was carried out to determine the feasibility of the pre-assembled kit of face-mask and HEPA filter adapted on a pre-set plastic-blanket. The first step consisted of washing hands, putting on safety glasses and gloves as the first personal protection equipment (PPE) elements and then covering the victim with an assembled plastic blanket. The second step consisted of 10 minutes of cardiopulmonary resuscitation (CPR) with PPE and plastic blanket, following the technical recommendations for ventilation during COVID-19.

**Results:** Ten rescuers took part in the pilot study. The average time to put on PPE and place the pre-assembly kit on the victim was 82 s [IC 58-105]. After 10 min the quality of the resuscitation (QCPR) was 91% [87-94]. Quality chest compressions (CC) were 22% better than ventilations (V). Most of the rescuers (60%) thought that placing the plastic blanket over the victim on the beach was somewhat simple or very simple.

**Conclusions:** Resuscitation techniques in the COVID-19 era on the beach have added complexities for the correct use of PPE. The plastic blanket plus basic ventilation equipment resources could be a new alternative to be considered for lifeguards to continue ventilation while reducing risk transmission.

## 4.6. ARTICLE 6. SAFE ON-BOAT RESUSCITATION BY LIFEGUARDS IN COVID-19 ERA. A PILOT STUDY COMPARING THREE SETS OF PROTECTIVE PERSONAL EQUIPMENT


Figure 8. Screenshot of item identification, available at https://www.mscbs.gob.es/biblioPublic/publicaciones/recursos_propios/resp/revista_cdrom/VOL94/C_ESPECIALES/RS94C_202006074.pdf.

### 4.6.1 Evidence of Quality

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- Indexed in JRC: Quartile 3 (Q3) and in SJR (Q1).
- Repositories: Wos of Science and Scopus.

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Contribution in publication

Conceptualization of the idea. Manuscript writing leadership (first author). Data collection processing. Preparation of tables and conceptualization of figures. Preparation of the final version of the manuscript and the revised version.

### 4.6.2 Article abstract

**Introduction:** On-boat resuscitation can be applied by lifeguards in an inflatable rescue boat (IRB). Due to Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-COV-2) and recommendations for the use of personal protective equipment (PPE), prehospital care procedures need to be re-evaluated. The objective of this study was to determine how the use of PPE influences the amount of preparation

time needed before beginning actual resuscitation and the quality of cardiopulmonary resuscitation (CPR; Q-CPR) on an IRB.

**Methods:** Three CPR tests were performed by 14 lifeguards, in teams of two, wearing different PPE: (1) Basic PPE (B-PPE): gloves, a mask, and protective glasses; (2) Full PPE (F-PPE): B-PPE + a waterproof apron; and (3) Basic PPE + plastic blanket (B+PPE). On-boat resuscitation using a bag-valve-mask (BVM) and high efficiency particulate air (HEPA) filter was performed sailing at 20km/hour.

**Results:** Using B-PPE takes less time and is significantly faster than F-PPE (B-PPE 17 [SD = 2] seconds versus F-PPE 69 [SD = 17] seconds; P = .001), and the use of B+PPE is slightly higher (B-PPE 17 [SD = 2] seconds versus B+PPE 34 [SD = 6] seconds; P = .002). The QCPR remained similar in all three scenarios (P >.05), reaching values over 79%.

**Conclusion:** The use of PPE during on-board resuscitation is feasible and does not interfere with quality when performed by trained lifeguards. The use of a plastic blanket could be a quick and easy alternative to offer extra protection to lifeguards during CPR on an IRB.

# 5. DISCUSSION

# 5. DISCUSSION

The main objectives of this thesis were to analyze the profiles of rescuers (both lay-rescuers and professional lifeguards), to delve further into different strategies to improve the performance of professional rescuers and also to adopt safe behaviors through a series of recommendations adapted to the COVID-19 era. In this last part, strategies and materials which could be efficient for a faster, safer resuscitation without delaying assistance are also addressed.

The main findings were:

g) There are four dominant profiles of lay-rescuers, with different risks depending on their age, origin, motivations and experience.

b) Aquatic rescue is very demanding physiologically. As it is physically demanding, it therefore requires adequate recovery. This recovery can be accelerated with methods taken from professional sports (i.e. foam roller/electro-stimulation).

c) The use of a plastic blanket can be a fast and effective alternative in CPR performed by rescuers, both on land and an IRB, without delaying the initiation of ventilations.

## 5.1 LAY-RESCUERS, PROFILE AND TECHNIQUES

Drowning is a public health problem, but it still has very little media notoriety, despite the alarming numbers of drownings, especially in LMICs (2). An important part of the study of drowning has therefore focused on the profile of the rescuer. There are two types of rescuers, professional rescuers (known as lifeguards) and bystanders (known as lay-rescuers). The mission of lifeguards is to ensure effective prevention, actively monitor and intervene when necessary. The lay-rescuer is more altruistic, less professional and has a very heterogeneous profile. When non-professional witnesses have been faced with an aquatic incident until now, they have been recommended against entering the water to attempt a rescue (7,11,26,63,64). However this recommendation conflicts with numerous circumstances, such as:

a) location of the incident (mostly between 50 and 100 m)(65,66),

b) relationship with the victim (26,64,67),

c) cultural aspects such as the case of Australian surfers who contribute significantly to rescues on unguarded beaches (27).

Until now, the aquatic rescuer has been treated with dichotomous differentiation: if he is a lifeguard then he can rescue, if he is a lay-rescuer, it is only recommended to try from out of the water - "reach, throw and don't go" – i.e. using a paddle or branch, throwing a rope, buoy or any floatation device(7,11,68). While this should definitely be

the first option, several doubts do arise; will the lay-rescuer have enough skill and precision to reach the victim in his radius of action? An Australian study showed the poor ability of people throwing a rescue bag (rope) to a victim who was feigning drowning(63). What would a lay-rescuer do if he/she didn´t have anything nearby to throw or no way of approaching a victim? Does a drowning victim have the ability to reach a nearby object? What if he/she is already unconscious? What would most fathers, mothers or older siblings do if they saw their child/sibling drowning? Would they try to find help, a flotation device or would they have an impulsive tendency to rescue?

It seems that the most repeated human behavior is to attempt rescue, which on numerous occasions causes what has been defined as *Aquatic-Victim-Instead-of-Rescued syndrome (AVIR)(*26), which consists of attempting to rescue a drowning person, and becoming a victim during the attempt. In view of this impulsive behavior and in order to mitigate the consequences of an inexperienced rescue, some Australian scientists suggest that every bather should have *"tools for heroic acts"*(69) in his or her beach equipment. This position is certainly debatable, but also very realistic. So the main question for lay-rescuers (P) is to what extent there are rescue techniques(I), which compared to making no attempt (C), do not increase the risk or expose the rescuer (O) to greater danger. It is precisely this PICO question that the first article of this doctoral thesis has tried to answer.

Lay-people rescuing relatives or friends is frequent (27,70), and the attempt involves a high risk (67,71-73). This is particularly dramatic in the case of LMICs in which the usual profile is of an older sibling rescuing a younger sibling, with both ending up drowned (74). Scientific literature has shown that these rescue attempts are often body-to-body, without the use of flotation devices. The outcome is often fatal, both for the victim and the rescuer, who often ends up as a second victim. The literature has so far not identified any safe technique with or without material in the water, so for this profile (occasional lay-rescuer, without experience or knowledge of rescue and acting impulsively), the recommendation of not entering the water remains the most appropriate one. Even so, it is necessary to study how to avoid this human instinct of *"duty of care"* (69) which pushes parents, siblings and friends to try to rescue even without having any type of aquatic competence.

For two of the profiles found: 1) *Children rescuing children* and 2) *Adults rescuing adults or children*, it is possible that education plays a fundamental role in the process of facing the risk as safely as possible. So far, scientific proposals have been based on incident prevention (17,75), but there are no references on how to control impulses and make the right decisions at the time of rescue. The drowning research community could take the studies on CPR with children as a reference (76,77). This is a good field to learn how appropriate decision making

can be trained with as little exposure as possible (78). The WHO further recommends "training bystanders in safe rescues and resuscitation"(1).

The review that forms part of this thesis, *"Lay-rescuers in drowning incidents: a scoping review"*, shows two other types of lay-rescuers with cultural motivations, experience or education in aquatic safety (14). On the one hand, there are those witnesses who, without having a family relationship (children, friends, relatives), attempt the aquatic rescue, either due to the *"duty of help"* or because they have basic rescue skills. This group includes police officers, firefighters and citizens of places with a high awareness of aquatic risk (79,80). In recent years, many emergency and security teams (not first responders) have included rescue equipment such as life-lines or rescue buoys in their equipment. In some locations, firefighters have the competence for water rescue (i.e. in the city of Pontevedra in Spain). This movement towards an aquatic response by police or firefighters occurs because in temperate zones lifeguards are only available in summer and have limited schedules (80).

It is important to note that police officers, firefighters or military personnel do not replace lifeguards, as their training is not as specific. The recommended techniques for this group are still rescue attempts without entering the water, but if they choose to perform a rescue in the water, they should use flotation equipment to avoid tragedies such as the one that occurred on the Orzan beach (La Coruña, Spain) in which several policemen died trying to rescue a swimmer.

The fourth profile identified in the literature consists of surfers who rescue bathers (27,66). The question arises as to whether these athletes can be classified as lay-rescuers, since as a result of their physical conditions and experience, they may have developed adequate knowledge to respond to rescue situations, even adverse ones. Attar et al. estimated that in Australia, rescues performed by surfers are on a par with rescues performed by volunteer rescuers, and their actions are performed both in places monitored by rescuers (45%) and in unmonitored places (53%)(27). A relevant aspect of this study is that surfers attribute their rescue expertise to the number of years of surfing experience (not to their training in rescue techniques). One aspect to highlight is that surfers use their surfboards as a rescue tool. This equipment has been shown to be the most efficient in terms of time/effort (31,81). It therefore seems reasonable that this profile of lay-rescuer who is already in the water and has flotation equipment can act as a lifeguard when encountering a victim in distress.

As a synthesis of this first part of the discussion, *Figure 9* summarizes the technical recommendations for lay-people rescues in and out of the water, related to their training and experience.

| | 1. OUT THE WATER | | 2. IN WATER | | | |
|---|---|---|---|---|---|---|
| **Type of techniques identified** | **Non-contact techniques** | | **No-contact techniques using a flotation device** | | **Contact techniques** | |
| **Ability and experience of lay-rescuer** | Untrained LAY-RESCUER | Trained LAY-RESCUER* | Untrained LAY-RESCUER | Trained LAY-RESCUER* | Untrained LAY-RESCUER | Trained LAY-RESCUER* |
| **Benefit vs. Risk** | **Benefit > Risk** | **Benefit > Risk** | **Risk > Benefit** | Probably **Benefit ≥ Risk** | **Risk > Benefit** | No evidence Expert opinion assume **Risk > Benefit** |
| **Rescue attempt** (force of recommendation) | Strong in favour | | Strong in favour | Weak in favour** | Strong in favour | Strong in favour |

Figure 9. Theoretical risk. Vs. Benefits rescue techniques for lay-rescuers. Original figure published in Barcala-Furelos R, Graham D, Abelairas-Gómez C, Rodríguez-Núñez A, Lay-rescuers in drowning incidents: A scoping review. Am J Emerg Med. 2021 Jan 31;44:38–44. Reproduction with editorial permission.

## 5.2 LIFEGUARDS, PROFILE AND TECHNIQUES

Lifeguards are the professionals who are in charge of prevention, surveillance and intervention in the event of an aquatic incident. Their task is to provide high standards of quality care, with the aim of avoiding any contingency in the aquatic environment and its surroundings. Drowning is a time-dependent critical event (6,25), so it must be attended to quickly and hypoxia must be treated early. It is for this reason that in recent years, research with lifeboats has taken special interest. The recent review promoted by the *International Liaison Committee on Resuscitation (ILCOR)* has identified seven studies of

clinical interest (82), one of which is part of this doctoral thesis; *Is "scoop and run while playing" resuscitation feasible on a rescue water craft? A randomized simulation study with lifeguards.*

Out of these lifeboat studies, only two articles presented clinical results with real patients (41,83), while the rest show results from simulation scenarios with manikins (43,45,46,57,84). Simulation studies addressed the ability of lifeguards and fishermen to perform on-board CPR in different conditions (with waves, wind, and at different speeds) as well as the use of the Automated External Defibrillator (AED). Within this field of literature, there is one study that has a special feature, as it addressed for the first time the feasibility to perform mouth-to-mouth resuscitation or on-boat CPR on a Rescue Water Craft (RWC).

Figure 10. Mouth-to-mouth resuscitation and CPR on the RWC. (Own photographs)

This study is based on two vital concepts: buying time and treating hypoxia, and therefore proposes a response to a classic debate on pre-hospital treatment in special *"stay and play"* or *"scoop and run"* situations (85).

We start with the assumption that an aquatic scenario is not a safe place or a controlled environment and thus always involves risk (86), so the

*"stay and play"* option always involves greater exposure both for the rescuer and the victim. Even so, the scientific literature shows examples in which *"stay and play"* is a vitally important alternative, as in the technique known as in-water resuscitation (39). Specifically, this technique has also been analyzed in the ILCOR review, which analyzed five studies that met the inclusion criteria (82). Only one Brazilian study presented retrospective data on actual patients, comparing those who received in-water resuscitation vs. those who did not receive in-water resuscitation. The survival of the in-water resuscitated cohort was significantly better (57% higher) than those who received CPR after being removed from the water (39). On the other hand, being in the water has many other disadvantages in relation to the safety and prognosis of the victim; maritime phenomena, cold water or the difficulty in adequately assessing the damage, have made the *"scoop and run"* option the usual one in lifeguarding. Our proposal is based on the principle of not delaying resuscitation while the victim is being evacuated and we have called it *"scoop and run while playing"* (57).

Before arriving at this conclusion, there are some antecedents that should be mentioned. The study by Tipton et al. analyzed the quality of CPR by comparing different boat sizes and sea states (waves etc.) (46). However, this type of boat is not used by beach lifeguards. The usual model on beaches is the Inflatable Rescue Boat (IRB). Five articles have been identified on IRBs, two Dutch ones (41,45) and three Spanish ones (42-44).

The set of Spanish studies conducted entirely by our research team showed how the quality of CPR in an IRB could be included in the *"stay and play"* option. This pilot study developed on the beach of Coroso (Ribeira-A Coruña, Spain) by means of a related samples test, compared the quality of CPR both on land and on board the ship (42). The next step was to test the feasibility of CPR when sailing, and the first tests were performed on fishing boats at different speeds and with changing wind conditions (84,87). *Figure 11*

The second relevant study of our research group, entitled *"Can surf-lifeguards perform a quality cardiopulmonary resuscitation sailing on a lifeboat? A quasi-experimental study"* published in Emerg Med J. 2017 Jun;34(6):370-5.(43) aimed to evaluate the influence of speed on Q-CPR. It was performed in Santiago del Teide (Canary Islands, Spain), with summer conditions and no adverse weather phenomena. This study showed that Q-CPR at 10 knots (18.52 km/h) was acceptable and although it meant an increase in rescuer fatigue and a slight decrease in quality, it is reasonable to think that it is a viable option and should be taken into account with real patients. *Figure 11.*

Figure 11. Image 1: First pilot study on Quality CPR sailing on a fishing boat. Figure 2: Second study in IRB (own photographs).

This study is connected with Section 4 of the *European Resuscitation Council Guidelines for Resuscitation 2015* (ERCGR2015), which recommends the use of lifeboats for greater rescuer safety (60). However these guidelines do not currently propose any type of on-board treatment. This study provided novel data on this possibility and introduced the idea of what we would later refer to as *"scoop and run while playing on-boat"* (57).

IRBs are maneuverable, fast and used all over the world by different rescue agencies (42,43), but there is also another type of lifeboat which is even more maneuverable and is also common in surveillance and rescue operations (57). RWCs are used both on large beaches and in wild areas, and are very common in surfing competitions and other nautical sports. RCWs usually have a sled of variable dimensions, and

can operate with a skipper-surfer alone, or with two operators; skipper-surfer and lifeguard.

Our research hypothesis aimed to evaluate for the first time the feasibility of CPR and its quality in RWC, in two different forms of resuscitation; 1) mouth-to-mouth resuscitation [emulating in-water resuscitation] and 2) Standard CPR (CC and V).

In order to compare the results with those obtained in IRB, the study was designed at the same speed (10 knots), the same duration (2 min) and the same sea conditions (no waves and a summer environment). In this case, the CPR technique had to involve *bow riding*, as this is the way the rescuer navigates on the sled. To avoid bias in the use of the technique, a brief training was conducted to familiarize the lifeguards with this new way of performing CPR.

The findings in relation to Q-CPR were similar to other studies in IRB (43). In this investigation, the experience of the rescuers differed. Those rescuers with experience in RWC barely suffered a decrease in Q-CPR compared to those on the beach, but for less experienced rescuers, the quality decreased significantly. In any case, all lifeguards, regardless of their education or training, were able to perform both techniques (MM-only and CPR).

This study differentiated ventilations in two variables: a) effective ventilation (i.e., when air enters and the chest is visibly raised) and b) quality of ventilation, when the volume recommended by the

ERCGR2015(60) between 500 and 600 ml is introduced. Lifeguards manage to introduce air in one out of two ventilations and insufflate adequate volume in 1 out of 3 ventilations. Difficulty ventilating during navigation is increased with speed and although this study has not tested this, it is also likely to be affected by wave size. Ventilation is the key factor in reversing hypoxia (6), and lifeguards should systematize training processes to optimize these results. While said results are not bad (doing nothing would be the worst scenario), they can definitely be improved significantly.

The improvement of skills is based on both technical and physical training, since lifesaving puts high physiological demands on people (35). A common finding in all studies on lifeguards is fatigue in their interventions. This occurs both in IRB (43) and especially after swimming rescues (28,30,31,34,50). Some studies have found that physical fatigue can influence the quality of post-rescue CPR(28,29,34) and several articles have focused on the need for physical fitness standards for rescuers (35,88-90). An aquatic rescue must be fast and vigorous (30), and even at relatively short distances (75 to 100 m), it will invariably generate a submaximal physiological load, consisting of a production of lactic acid greater than 10 millimoles of lactic acid per liter (mmol/l) (30,31,50) along with perceived exertion values qualified as *"extremely tough"* after aquatic rescues (31,59).

Lifeguards must be in good physical shape to perform rescues (35,88) and unlike in sports rescue, in professional lifeguarding they must

continue working after performing a rescue. Working hours in Spain are usually eight hours a day, and sometimes rescuers must perform more than one rescue in the same day (66). Such a demanding effort requires a recovery period. This physiological restoration process can take up to 48 hours.

One of the challenges of this thesis was to analyze how to attenuate the effect of acute fatigue on rescuers, by looking for strategies to aid their recovery without interrupting their professional work. A previous study by our research group compared the effect of three recovery strategies (passive recovery: sitting while watching the beach, active recovery: running and active recovery: with foam roller Figure 12), after a high intensity aquatic rescue (50).

Figure 12. Active recovery technique with Foam Roller (own image).

The results showed that the passive type of recovery (the rescuer watching in a chair) was the least efficient, since the rate of decrease in lactate concentration was significantly lower ($p<0.05$), so the dilemma arose as to what would be more appropriate: to recover actively to quickly decrease the high lactacidemia or to continue with the surveillance even if the passive method takes longer in the recovery process?

There is no single answer to this question, as it will depend on the number of rescuers on duty and the resources available.

The use of foam roller for the recovery of lifeguards was something new and low cost, never tested until then, and it enabled the ability to maintain relative attention while watching the beach, and this was the reason why we experimented with this new, inexpensive cylinder. The use of foam roller focused on self-massage of the lower limb musculature: quadriceps, iliotibial tract, hamstrings, adductors, and gluteus and the protocol lasted approximately 25 min (50). We focused only on the lower limbs because this is the part of the rescue in which only the legs are involved (victim to-in). This phase lasts 3 times longer than the first part of the rescue in which hands and legs are used propulsively as the swimmer approaches the victim (30).

This formula offered an alternative for the first time, so that rescuers could now perform active recovery while maintaining a relative focus on their surveillance tasks.

However, we had not yet found a system that would accelerate recovery without affecting any of the lifeguards' surveillance skills. It is at this point, based on a multidisciplinary team work with lifeguards, physicians, nurses, physical educators and physiotherapists, that the use of electrostimulation is proposed for use after aquatic rescue.

A controlled collaborative study was carried out between the University of Vigo, the University of Santiago de Compostela and the University of Coimbra, in the Portuguese coastal town of Figueira da Foz. After a 100m rescue, a biphasic square wave current was applied at 5 Hz, with a phase duration of 0.25 milliseconds. The electrostimulation time was 20min. The location of the electrodes was in the quadriceps of both legs. The rescuers performed the rescue with fins, and the scientific literature shows that during the crawl kick with fins, the muscle with the greatest involvement is the rectus femoris (91).

The results obtained showed physiological values to be taken into account. The electro stimulation significantly reduced the decrease in lactate concentration and showed a tendency towards a lower RPE although it did not show significant values ($p>0.05$). These results are explained by the effect of ES on pain reduction, its analgesic effect (92) and lactate reduction, effects. Although there are no studies with lifeguards that have evaluated this parameter, they do seem to be in line with the swimming literature (92).

One of the criticisms/comments of the reviewers was that in a field as precarious as lifeguarding, especially in LMICs, this type of work is not of relevant interest, since they have other deficient and higher priority fields. This reflection is important, because the objective we have with our studies is to seek the highest standard of quality, whether in prevention, rescue or resuscitation. With this system we have managed to accelerate recovery without altering the surveillance functions of the rescuer. *Figure 13*

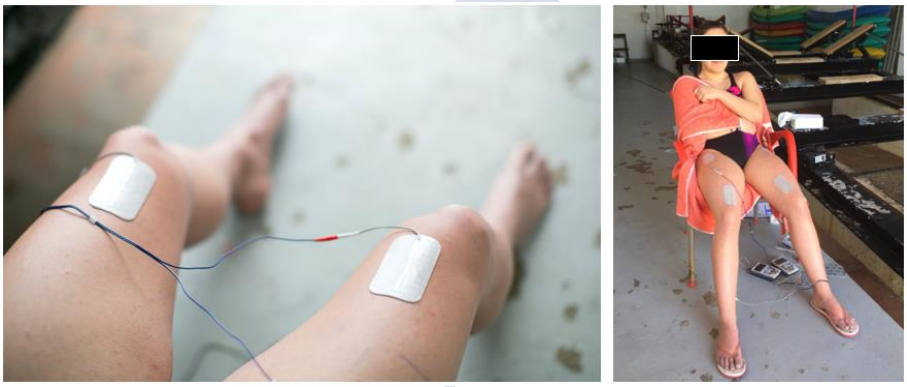

Figure 13. ES recovery technique (own image).

In summary, this first part of the discussion addressed the two types of rescuers in the aquatic environment; lay-rescuers and lifeguards. For lay-rescuers, we identified four different profiles and offered an evidence-based recommendation on the risk/benefit of attempting aquatic rescue from out-of-water and in-water (with and without flotation devices). The results found will serve to educate the community and lifeguard teams, thus enhancing prevention-pre-event in the drowning timeline(12).

The studies on professional lifeguards focused on the event (reaction) and post-event (mitigation) (the last two phases of the drowning timeline) (12). The two studies aim to gain time, the first in drowning mitigation, introducing the concept of *"scoop and run while playing"* in RWC, and the second, to mitigate fatigue as soon as possible, by looking for the best recovery strategies.

What was innovative was the identification of profiles in lay-rescuers, the evaluation of two new CPR techniques aboard RWC and the application of a new ES recovery technique, which allows rescuers to remain vigilant while speeding up their recovery. These studies are a continuation of previous research related to the quality of CPR in IRB (42,43) or the evaluation of different methods of physiological optimization after rescue (50).

### 5.3 SARS-COV-2 AND LIFEGUARDING

"Half of what we currently know about medicine will be proven wrong in 10 years, yet as of today, we still don't know what part it is." This quote from the dean of medicine at Harvard Medical School has been experienced within a year with the emergence of a zoonotic virus called Acute Respiratory Syndrome Coronavirus-2 (SARS-COV-2). This virus with a single-stranded RNA genome, which causes the disease called COVID-19 in humans, has changed in just a few short months, the global lifestyle and medical principles of action (both in the

prevention of contagion and treatment of the disease). It has led to an unprecedented race in science, to get a vaccine in a period of one year, which was something unthinkable until now. The World Health Organization (WHO) declared the COVID-19 pandemic on March 11, 2020 (52). After its appearance in China at the end of 2019, the jump to Europe seems to have been around January 2020, initially affecting Italy, followed by Spain and spreading rapidly and uncontrollably throughout the rest of the continent (and the world).

One of the first consequences of SARS-COV-2 was the high rate of infectivity, which affected front-line healthcare personnel (93). This circumstance occurred due to the initial lack of knowledge about the virus´ transmission, its etiology, and also due to the absence of adequate personal protective equipment (PPE).

After the confinement decreed by the Spanish Government, and while the first wave began to subside, we entered May/June, just at the beginning of the summer season, and no one had thought about lifeguards, nor about their training to face the first summer of the COVID-19 Era, nor about the use of PPE on the beach, nor about the technical modifications required for rescue and resuscitation procedures for drowning.

The European Resuscitation Council (ERC) quickly published guidelines for contagion prevention and resuscitation in COVID-19 (94), but these guidelines had no real focus on the work of lifeguards,

as they limited ventilation to Advant Life Support (ALS) teams, and promoted only-hands CPR for any provider (even professional) at the first moment.

The prevention of contagion by droplets was based on respiratory physiotherapy studies with conscious and seated patients (95) and there was not yet much evidence on aerosols and they were based on mathematical models of particle behavior (96).

With these first recommendations, there were major limitations of real application, which are listed below.

1. The models and criteria based on droplet and aerosol transmission were based neither on the position nor on the real context of the victim and rescuer.

2. The clinical recommendations did not address the real needs of a drowning victim (combat hypoxia - therefore ventilate as soon as possible).

3. The recommended protection systems are of doubtful application in aquatic contexts for the following reasons: a) they do not meet the real protection criteria -e.g. Surgical mask on wet patient-, b) difficulty of its use in natural environments (wind, water, sand, remote environments or boats), c) lack of PPE distribution -in the first wave-, d) training of lifeguards in the use of PPE.

Therefore, for drowning in general and lifeguarding in particular, there were a number of challenges that needed to be resolved in a short period of time. The goal was to provide safe, quality conditions for interventions in the first COVID-19 summer. Our initial challenges were twofold:

1- Compile all available information on COVID-19 prevention and first aid treatments, including BLS, to be adapted to the needs of lifeguards.

2 - Search for alternatives for resuscitation, with greater applicability to the lifeguard's environment (beach and boats).

As a starting point we knew that *social distancing* was up until now the best measure of protection and the minimum recommendation was a separation of 2 meters (97), but that in special circumstances (for example with wind or depending on environmental humidity) the drops could reach up to 8 meters (96,98) and the aerosols, in closed or non-ventilated places, could remain in the air for hours. However, both for rescues and for many interventions by rescuers, it is not possible to keep a distance or even to use PPE adequately.

With this initial information, a task force was created by the Spanish Society of Emergency Medicine (SEMES) lifeguard working group, together with other drowning researchers, to promote self-protection and intervention recommendations for lifeguards, which was finally published in June 2020 in the Revista Española de Salud Pública, belonging to the Ministry of Health (Government of Spain).

This group prepared a guide organized in four sections: 1) Prevention of contagion, screening of positives and risks for the lifeguard, 2) Personal protective equipment (PPE). Possibilities and limitations, 3) Reaction to drowning. Water rescue. 4) Mitigation: pre-hospital care and basic life support for drowning.

1) Prevention of contagion, screening of positives and risks for the rescuer.

In the early stages of the pandemic, in addition to high community transmission of the virus, there was also a high rate of infection of health providers (93,99). A protective factor for lifeguards is that they work outdoors on the beaches and that the average age of lifeguards in Spain is less than 30 years; however, other risk factors should be considered, such as wind, the flow of tourists from places with a high incidence of COVID-19 and asymptomatic persons infected by COVID-19.

The working group proposed the following general recommendations for first aid workers.

- Hand washing before and after contact with the patient, and in general, whenever deemed necessary.
- Permanent protection during assistance with FFP mask and use of sunglasses.
- Inform users or hold conversations upwind of people.

- Disinfection of communication equipment, and distribute to each lifeguard their own communication equipment. Failing that, use personal cell phones.
- COVID-19 screening is proposed, outside the watchtower or first aid station. The lifeguard will be fully clothed, behind a vinyl screen or upwind of the user and for minor treatments self-indications will be given.
- The division of spaces is recommended for both health care and surveillance. The main measures can be found in *figure 14*.

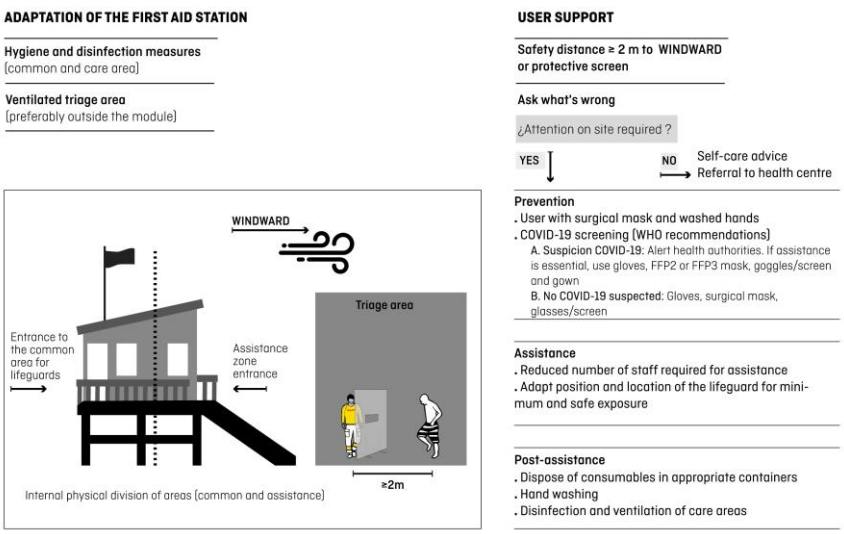


Figure 14. Diagram on adaptations of the first aid module and patient care by the lifeguard. Published in Revista Española de Salud Pública by Barcala-Furelos et al. (55) under Creative Commons license and reproduced with their editorial permission.

1) *Personal protective equipment (PPE). Possibilities and limitations and 3) Reaction to drowning.*

After the first wave, it was decided to consider that any person requiring assistance is a potential SARS-CoV-2(94) carrier, until proven otherwise. Therefore, for the safest possible assistance, it was necessary to rethink the ideal PPE with the actual PPE that can be used by first responders. This section presented another new challenge, since there is no previous experience in the use of PPE among first responders, but there are also a number of additional difficulties that were noted by the working group that developed these recommendations.

Prehospital care on land (the beach), and prehospital care in the water were differentiated. The aquatic part had the following conditioning factors:

- Little or no likelihood of maintaining the safety distance.

- Aquatic rescues with surrounding aerolizations (due to not being able to maintain the safety distance).

- Habitual coughing and secretions from the early stages of drowning (6).

By consensus of experts, with the information available at that time and with the adaptation to the work of the rescuer, *figure 15* was proposed, which includes the feasibility of the use of PPE in relation to the type of intervention.

| PROTECTION | PROTECTION EQUIPMENT | WATER RESCUE | | GROUND ATTENTION | |
|---|---|---|---|---|---|
| | | From ship | From inside the water | Assessment and reanimation | Non-emergency care at the first aid station |
| Mucosa of the eyes | **Full glasses** | XX | - | XX | XX |
| | **Lifeguard / Diving Glasses** | X | X | X | X |
| | **Screen** | - | - | XX | XX |
| | **Full-screen helmet / or full-face helmet** | XX | - | X | X |
| Airways | **FFP2 and FFP3 mask** | XX (FFP2) XX (FFP3 if resuscitation on board) | - | XX (FFP3) | XX (FFP2) |
| Skin | **Nitrile gloves** (can be combined with neoprene gloves) | XX | - | XX | XX |
| | **Double latex or vinyl gloves** (can be combined with neoprene gloves) | X | - | XX | XX |
| | **Complete suit: Long-sleeved waterproof gown or disposable coverall against infectious agents** | - | - | XX | XX |
| | **Complete suit: Common long-sleeved gown or complete work uniform** (long sleeves, long pants) | - | - | | X |

XX: protection (described as PPE in Covid-19); X: some protection (usual material in lifesaving or means of fortune); -: not feasible or not recommended in the technique/environment.

Figure 15. Feasibility of the use of PPE and other protective equipment in the different lifeguard interventions. Published in Revista Española de Salud Pública by Barcala-Furelos et al.(55) under Creative Commons license and reproduced with their editorial authorization.

In this analysis of the material, and knowing the difficulties of its use, as well as the cost/benefit of the intervention, a hypothetical grading

was made of the risk related to the rescue material used. The materials with the lowest risk are those that involve non-contact flotation, such as drones, rescue bags, poles and other non-contact approaches or flotation materials. Medium risk was considered for rescues with less close contact, but without the possibility of maintaining safe distance, as in IRBs. High risk was considered for non-motorized vessels (canoes and paddle surfboards), where space is more limited and exposure time is longer. Finally, the highest risk was for rescue techniques that require direct contact with the victim, such as body-to-body water rescue *(Figure 16).*

| Thecnique | Non-contact methods | Short-term contact with possibility of using PPE | Longer contact time with limited use of PPE | Full contact, no PPE possible |
|---|---|---|---|---|
| Risk | LOW | MEDIUM | HIGH | VERY HIGH |

Figure 16: Gradation of the risk of contagion in relation to the rescue procedure used. (Figure prepared by the authors).

*4) Mitigation: pre-hospital care and basic life support in drowning.*

This section was particularly controversial. Researchers in the field of drowning reacted quickly to the new recommendations for Basic Life Support (BLS) in which ventilations took second place (94). The challenge of the new recommendations was to avoid aerosol transmission during CC, and in the administration of V it was necessary to ensure safety by using barrier materials, HEPA filters and PPE.

Both IDRA and our working group proposed resuscitation algorithms to provide the best drowning care. Our working group's algorithm maintained the essence of the ERCG2015 drowning recommendations, adding the use of PPE (60) *Figure 17*. The IDRA recommendations were less conservative, as they included the bag-valve-mask, pocket mask or passive ventilation as alternatives (54). These recommendations are intended for a more global audience.

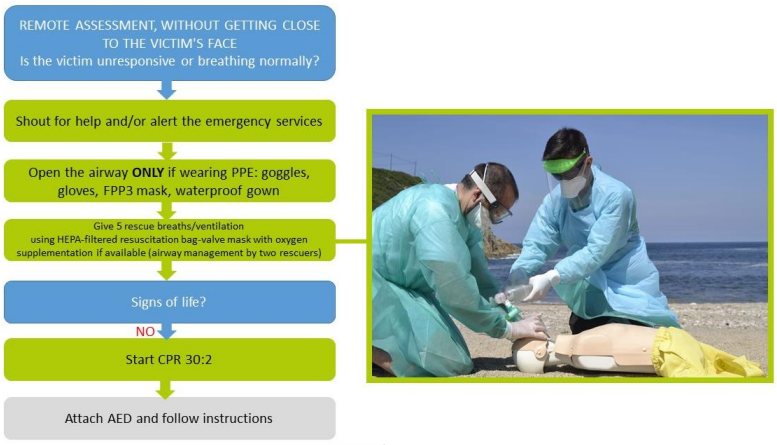


Figure 17. Adaptation of the drowning basic life support algorithm according to ERC2015 (60) recommendations to the Covid-19 era according to ERC2020 (94) recommendations. Published in the Revista Española de Salud Pública by Barcala-Furelos et al. (55) under the Creative Commons license and reproduced with their editorial permission.

The use of PPE requires training, as well as experience, concentration and assistance in its use. This is not possible in most rescue procedures, especially after a rescue (58), when the rescuer emerges wet and fatigued (31), usually at a location away from the first aid station. After rescue, the ABCDE approach should be initiated, and basic CPR

initiated if necessary. Rescuers often have a portable emergency bag (PEB) for first aid, with essential equipment: Airway: Oropharyngeal airway, suction equipment, Breathing: Oxygen, bag-mask, face-mask, Circulation: Automated external defibrillator, wound dressing, hemostatic dressing, tourniquet. Disability: None, Exposure: Warning blanket (100).

The new pandemic situation would require the inclusion of all protective equipment (PPE). However, its proper use in aquatic environments can range from difficult to impossible.

Based on the hospital experience of anesthesiologists during intubation and extubation, using plastics for extra protection during airway interventions (101), as well as the study by Chan et al. showed the use of HEPA filter in bag-valve-mask dos not prevent 100% air leakage (102), which motivated us to look for the application of plastic blankets as a protective alternative in BLS performed by lifeguards.

The first pilot study with plastic blanket in this thesis aimed to analyze the feasibility of its use on the beach (58). Our hypothesis is that the plastic blanket is an alternative method of protection that does not affect the quality of CPR, in addition to allowing rapid placement without delaying the start of ventilations. Other advantages are low cost and ease of use, which is necessary for professionals who do not have specific training or use PPE for resuscitation on a daily basis.

Our design consisted of transparent plastic 250 cm long by 150 cm wide, in one part of which a face-mask with a HEPA fligrotor was pre-assembled. The kit is composed of 4 to 6 horseshoe spikes. This plastic integrated in the first aid case allows rescuers to cover the victim and start ventilations in 82 sec. on average. *Figure 18.*

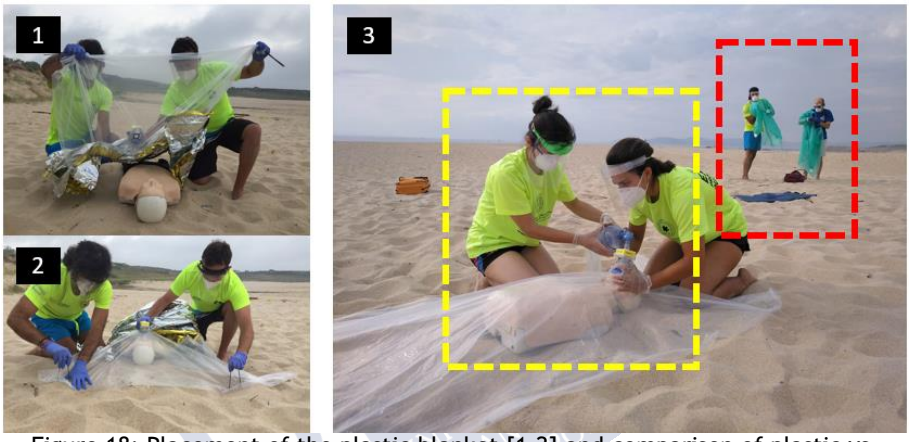

Figure 18: Placement of the plastic blanket [1,2] and comparison of plastic vs. apron blanket [3]. (Own images).

CPR quality was of high quality, with a value of 91% in 10 min resuscitation. Compressions were better than ventilations, as is usual in other simulation studies with rescuers using the same Laerdal Q-CPR measurement system (30,31,34). Another relevant aspect was that a large proportion of the rescuers considered that using this plastic kit was simple, compared to using full PPE (with an apron).

In the arena it may be more or less debatable to use full PPE or to use alternative PPE (i.e. the plastic blanket), as the availability of resources, training, victim location or quick EMS assistance may offer different

alternatives. However, at the first moment of IRB rescue there are not many alternatives. The rescuer must choose between starting ventilations as soon as possible or delaying them, depending on the level of protection of each set. Even so, based on our background, we consider that the ideal PPE model (with apron) may be unfeasible in IRB, generate a false sense of protection and delay the start of resuscitation. Under this premise, we compared three PPE sets in an IRB sailing at 20km/h, again comparing the Q-CPR, and analyzing the set preparation time until the start of the first ventilation (44). *Figure 19.*


Figure 19. Comparison of plastic blanket set on IRB [1] vs. full PPE with apron [2]. (Own images).

The first important finding was that the time to first ventilation was 17s with a basic protection level, 34s with protection based on a plastic blanket and 69s with full PPE equipment. That is, wearing full PPE takes 30s more, 43% of the rescuers used it incorrectly or its placement was incorrect, with large exposed body areas. In the resuscitation test

there were no significant differences with any of the three sets and the values were around 90% Q-CPR. It is now accepted that a value equal to or greater than 70% in simulation could be considered quality CPR (103).

Protection during emergencies has become essential, but recommendations focus on the most common "medical" settings (i.e. hospitals or ambulances), in which the means, experience and scenario is usually controlled (44). Protection is important, but so is treatment. An IRB is the fastest means at sea to interrupt the drowning process (43). Speed contributes to reducing submergence time, which is the most important determinant of drowning victim outcomes (25). Lifeguard agencies should consider the local incidence of the virus in their protocols, the age of their rescuers (usually young), vaccinated rescuers and the local vaccination rate or those rescuers who have already had COVID-19, for the choice of the level of protection during on-boat resuscitation. If maximum protection is chosen, it should be noted that the full use of PPE requires training (55,104,105) and a stable and safe place for its placement.

### 5.4. PRACTICAL IMPLICATIONS

This thesis has sought to provide clues to resolve numerous practical situations in a special environment and with events that are difficult to

compare to other clinical settings. Our studies have focused on rescuers (lay and professional) and have served the following purposes:

*Lay-rescuer:*

- Establish appropriate prevention campaigns for each type of lay-rescuer.

- Promote out-of-water rescue and self-rescue skills training for lay-rescuers at higher risk.

- Promote rescue and resuscitation skills training for lay-rescuers who, due to their characteristics, have the experience, training and fortune to be in the water when performing a rescue (i.e. surfers).

***Professional rescuers:***

- Implement new possibilities to start resuscitation as soon as possible, especially providing ventilations from the first moment of drowning.

- Improve the physical conditions of the rescuers, so that they can recover as quickly as possible.

- To offer recommendations and resuscitation protocols to treat drowning, analyzing the different means of self-protection based on the characteristics of the aquatic environment.

## 5.5 LIMITATIONS

Limitations have been pointed out in all the articles that make up this thesis. Generally speaking, the main limitation of the experimental studies is that they are simulated situations, with local and relatively small samples. They are reproducible pilot studies that can generate greater knowledge if they are studied with other populations, other resources and applied to real cases. Future research should support the usability of our proposals, which are based on existing medical evidence and the research background in the first aid field.

# 6. CONCLUSIONS

# 6. CONCLUSIONS

This doctoral thesis groups the conclusions into three blocks, related to the hypotheses of the different papers that make up the compendium of publications. The blocks are structured in the analysis of the profile of rescuers (lay-rescuers and professional lifeguards) and the techniques and strategies to face a water rescue with differents levels of evidence. The second block of conclusions refers to resuscitation skills in special circunstances (drowning), adding the modifications derived from the COVID Era, and finally the third block refers to recovery strategies to mitigate the physical fatigue caused by water rescue in lifeguards. .

The conclusions of this doctoral thesis are presented below.

### CONCLUSIONS ACCORDING TO HI

There are different profiles of lay-rescuers, with variability in their capabilities and different risks during their rescue attempts. Four profiles have been identified: children rescuing children, adults rescuing children or adults, lay-rescuers with experience and hight water competence and adults with cultural or professional motivations for rescue.

Generically the lay-rescuer should not enter the water, however, lay-rescuers with knowledge and great aquatic experience (like surfers) who are in the water can be a great asset in drowning mitigation. There is no description of specific techniques for in-water rescue of lay-people, other than that surfers may use their board as an aid. Out of the water there are no reports of how many people have been rescued by flotation devices, but there is ample evidence of drowning people attempting to rescue other victims.

### CONCLUSIONS ACCORDING TO H2

Early resuscitation is a goal of the pre-hospital emergency. In special situations like drowning. Early initiation of drowning resuscitation is possible, both in RWC and IRB, by adapting known techniques to the available space, rescuer position and sea conditions. In RWC the quality of ventilations and compressions is acceptable. The rescuer's experience is a determining factor for a good application of CPR.

Protection (i.e. PPE) in times of COVID-19 is possible, especially using a blanket plastic. The use of a plastic blanket has been successfully tested both on land and while sailing on an IRB, and it has not influenced the quality of CPR and has shortened the time to initiate maneuvers.

### CONCLUSIONS ACCORDING TO H3

A physical rescue is strenuous and causes a high rate of physiological fatigue, with elevated lactate levels. Physical fatigue after rescue may condition a second lifesaving. Active recovery methods promote faster physiological readjustment. ES can be a recovery alternative after a rescue allowing the rescuer to continue with his or her surveillance work.

# 7. FUTURE PERSPECTIVES BASED ON THIS RESEARCH

# 7. FUTURE PERSPECTIVES

# BASED ON THIS RESEARCH

The future areas of this research focus on four basic points.

1. Apply specific prevention strategies for each profile of person at risk of drowning, already identified in the literature. In addition to conducting a longitudinal study of the measures implemented, public health strategies should have a target audience and their effectiveness should be evaluated by means of data and not opinions. To achieve this, it is necessary to draw up an epidemiological follow-up plan.

2. Regarding surveillance, it is essential to continue research on how to identify the drowning person in order to interrupt the drowning process as soon as possible. So far there is hardly any evidence on how people drown, the most recent being by Bierens & Carballo-Fazanes (23). Deepening this knowledge is one of the main points in future research. Artificial intelligence has opened a door to the permanent monitoring of numerous aquatic spaces, but there are still many gaps, since artificial

intelligence is based on the processing of known and reproducible data that are not yet known.

3. During aquatic rescue, the lifeguard puts his physical capabilities to the test. However, few studies have analyzed with real applicability the physical and technical profile of lifeguards. Advancing in the physiological and technical knowledge of lifeguards can contribute to optimize their capabilities and mitigate their limitations. This future strategy not only includes preparation for rescue, but also the study of the most effective techniques, the most recommended materials and recovery strategies that can best help the rescuer to face a new rescue.

4. CPR must be rethought. After the COVID-19 era, ventilation have remained in the background, and only some scientific societies such as IDRA or SEMES have been concerned about keeping the use of ventilation in the wheel. It is important to remember that the origin of cardiac arrest in drowning is asphyxial, so the objective to be combated is systemic hypoxia. This has been aggravated by the limitations of mouth-to-mouth ventilation. It is necessary and vitally important to rebuild confidence in safe and effective ventilation in drowning victims. With immunization vaccination of the population, ventilation should again be promoted, either with pocket masks or even mouth-to-mouth as the benefits will outweigh the risks in victims with cardiac arrest of an asphyxial origin.

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# APPENDIX I: LINK TO PUBLICATONS

Barcala-Furelos R, Graham D, Abelairas-Gómez C, Rodríguez-Núñez A. **Lay-rescuers in drowning incidents: A scoping review.** Am J Emerg Med. 2021 Jan 31;44:38–44 https://pubmed.ncbi.nlm.nih.gov/33578330/

Barcala-Furelos R, Abelairas-Gomez C, Aranda-García S, Lorenzo-Martínez M, Martínez-Isasi S, Durán-Álvarez C, et al. **Is it 'scoop and run while playing' resuscitation feasible on a rescue water craft? A randomized simulation study with lifeguards.** Am J Emerg Med. 2020 Mar; 38(3):618–23. https://pubmed.ncbi.nlm.nih.gov/31982219/

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# APPENDIX II. PERMISSION FOR REPRODUCTIONS

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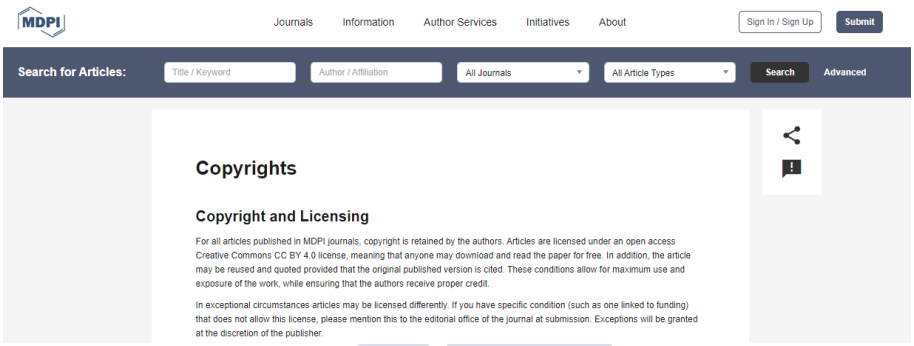




Barcala-Furelos R, Aranda-García S, Abelairas-Gómez C, Martínez-Isasi S, López-Mesa F, Oleagordia-Aguirre A, et al. **[Occupational health recommendations for lifeguards in aquatic emergencies in the COVID-19 era: prevention, rescue and resuscitation.].** Rev Esp Salud Publica. 2020 Jun 30;94.

Buenos días,



Un cordial saludo,

Mª Aranzazu López Franco

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On Wed, Mar 31, 2021 at 3:26 AM Roberto Barcala Furelos <roberto.barcala.furelos@gmail.com> wrote:

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> I am finishing my second PhD, and this PhD program was carried out by means of a compendium of publications.
> I wanted to ask permission to use a copy of the paper that I am author, published in the Prehospital and Disaster Medicine title "Safe on-boat resuscitation by lifeguards in Covid-19 Era. A pilot study comparing three sets of protective personal equipment" in my PhD book manuscript.
> I hope your news.
> All the best
> Roberto

# APPENDIX III.
# ETHICAL PERMISSION

Universidade Vigo | Facultade de Ciencias da Educación e do Deporte

Carlos Ayán Pérez, en calidad de Secretario del Comité de Ética de la Facultad Ciencias de la Educación y del Deporte (Universidad de Vigo)

HAGO CONSTAR:

Que el proyecto presentado por el equipo investigador formado por ***Roberto Barcala Furelos, Antonio Rodríguez Núñez, Cristian Abelairas Gómez, Santiago Martínez Isasi, Alejandra Alonso Calvete, y Francisco Cano Noguera,*** titulado **EQUIPOS DE PROTECCIÓN INDIVIDUAL Y EQUIPO DE PROTECCIÓN DE FORTUNA MEDIANTE MANTA PLÁSTICA. ESTUDIO DE SIMULACIÓN DE LA CALIDAD DE LA REANIMACIÓN CARDIOPULMONAR EN EMBARCACIONES DE RESCATE EN TIEMPOS DEL COVID-19** ha sido informado por dicho Comité, otorgándosele el siguiente código:

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Carlos Ayán Pérez, en calidad de Secretario del Comité de Ética de la Facultad Ciencias de la Educación y del Deporte (Universidad de Vigo)

HAGO CONSTAR:

Que el proyecto presentado por el equipo investigador formado por ***Roberto Barcala Furelos, Cristian Abelairas Gómez, David Szpilman, Antonio Rodríguez Núñez, María José Fernández Méndez y José Palacios Aguilar***, titulado **EVALUACIÓN DE HABILIDADES DE COMPRESIÓN Y VENTILACIÓN EN MOTO ACUÁTICA DE RESCATE. UN ESTUDIO PILOTO DE SIMULACIÓN CON MANIQUÍES**, ha sido informado por dicho Comité, otorgándosele el siguiente código:

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**To Whom It May Concern**

The project entitled *"Avaliação do efeito da electroestimulação na recuperação do nadador salvador após resgate simulado no mar"* (ref.ª CE/FCDEF-UC/00312018) of the research team: Doutor Luis Manuel Pinto Lopes Rama (IR-research leader), António Barcuela Furelos (University of Pontevedra-Spain), Olga Marques, was approved by the Ethics Commitee of the Faculty of Sport Sciences and Physical Education of the University of Coimbra.

Coimbra, 05/04/2021,

The President of the Ethics Commitee,

(Prof. Doutor Carlos Gonçalves)