International Journal of FIRST AID EDUCATION

Effects of Physical Fatigue on Cardiopulmonary Resuscitation Quality by Lifeguards: A Systematic Review and Meta-analysis

DESCRIPTIVE MANUSCRIPT

FILIPE MAIA
LUIS SOUSA
PAULO SANTIAGO
*Author affiliations can be found in the back matter of this article

aperio

ABSTRACT

Background: Lifeguards actively contribute to safeguarding human lives in aquatic environments. When attending to victims of cardiac arrest in the water, lifeguards must perform basic life support after intense physical exertion that may involve running, swimming, and towing. The purpose of this review is to assess the magnitude of the effects caused by physical fatigue on the quality of subsequent cardiopulmonary resuscitation, under simulated conditions.

Methods: A systematic literature search was conducted following PRISMA guidelines, covering the databases: PubMed, Web of Science, ScienceDirect, and Academic Search Complete, using the keywords: (lifeguard) AND ("cardiopulmonary" OR "cardiorespiratory" OR "basic life support" OR "resusc*"). Articles published until 25 May 2023 were considered for inclusion. The methodological quality of the included studies was assessed using the JBI Critical Appraisal Tool. The pooled data analysis was conducted using a random-effects model, with heterogeneity assessed using I^2.

Results: In total, 8 studies (297 lifeguards) were included. Results indicate that physical fatigue jeopardizes the quality of compressions (ES: –0.90) and ventilations (ES: –1.10).

Conclusions: In general, lifeguards perform cardiopulmonary resuscitation poorly, especially when physically fatigued. Hence, this underscores the importance of keeping these professionals prepared to perform basic life support.

RESUMO

Introdução: Os nadadores-salvadores contribuem ativamente na salvaguarda da vida humana em espaços aquáticos. Quando procuram dar resposta a vítimas de ataque cardíaco na água, estes profissionais devem realizar suporte básico de vida após atividade física intensa, que pode incluir correr, nadar e rebocar. O propósito desta revisão é averiguar a magnitude do efeito causado pela fadiga física na ressuscitação cardiopulmonar subsequente, sob condições simuladas.

Métodos: Uma pesquisa sistemática da literatura foi realizada seguindo as normas PRISMA, cobrindo as bases de dados: PubMed, Web of Science, ScienceDirect, and Academic Search Complete, usando as palavras-chave: (lifeguard) AND

CORRESPONDING AUTHOR:
Filipe Maia
Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD), University of Maia, Maia, Portugal
fm.filipemaia@gmail.com

KEYWORDS:
Fatigue; Resuscitation; Lifesaving; Rescue; Cardiac arrest

TO CITE THIS ARTICLE:
Maia, F., Sousa, L., & Santiago, P. (2023). Effects of Physical Fatigue on Cardiopulmonary Resuscitation Quality by Lifeguards: A Systematic Review and Meta-analysis. *International Journal of First Aid Education*, *6*(1), 70–80. DOI: https://doi.org/10.25894/ijfae.6.1.91

("cardiopulmonary" OR "cardiorespiratory" OR "basic life support" OR "resusc*"). Os artigos publicados até 25 de maio de 2023 foram considerados para inclusão. A qualidade metodológica dos estudos incluídos foi avaliada com recurso à JBI Critical Appraisal Tool. A análise de dados foi conduzida utilizando random-effects model, com a heterogeneidade avaliada usando o teste I2.

Resultados: No total, 8 estudos foram incluídos (297 participantes). Os resultados indicam que a fadiga física compromete a qualidade das compressões (ES: -0.90) e das ventilações (ES: -1.10)

Conclusões: De modo geral, os nadadores-salvadores realizam ressuscitação cardiopulmonar com má qualidade, especialmente sob fadiga. Assim, estes resultados ilustram a importância de manter nadadores-salvadores devidamente preparados para realizar suporte básico de vida.

RÉSUMÉ

Effets de la fatigue physique sur la qualité de la réanimation cardio-pulmonaire par les sauveteurs : Une revue systématique et une méta-analyse

Contexte : Les sauveteurs contribuent activement à la sauvegarde des vies humaines dans les milieux aquatiques. Lorsqu'ils s'occupent de victimes d'arrêts cardiaques dans l'eau, les sauveteurs doivent effectuer une réanimation de base après un effort physique intense qui peut impliquer la course, la natation et le remorquage. L'objectif de cette étude est d'évaluer l'ampleur des effets de la fatigue physique sur la qualité de la réanimation cardio-pulmonaire subséquente, dans des conditions simulées.

Méthodes : Une recherche documentaire systématique a été effectuée conformément aux lignes directrices PRISMA, couvrant les bases de données : PubMed, Web of Science, ScienceDirect, et Academic Search Complete, en utilisant les mots clés en anglais : (lifeguard) et ("cardiopulmonary" ou "cardiorespiratory" ou "basic life support" OU "resusc*"). Les articles publiés jusqu'au 25 mai 2023 ont été pris en compte. La qualité méthodologique des études incluses a été évaluée à l'aide du JBI Critical Appraisal Tool. L'analyse des données regroupées a été réalisée à l'aide d'un modèle à effets aléatoires, l'hétérogénéité étant évaluée à l'aide de I2.

Résultats : Au total, 8 études (297 sauveteurs) ont été incluses. Les résultats indiquent que la fatigue physique compromet la qualité des compressions (ES : -0,90) et des ventilations (ES : -1,10).

Conclusion : En général, les sauveteurs font mal la réanimation cardio-pulmonaire, surtout lorsqu'ils sont physiquement fatigués. Cela souligne donc l'importance de maintenir ces professionnels préparés à effectuer les soins de base.

Lifeguards' activity is fundamental to prevent accidents and contribute to the safeguarding of human lives in aquatic environments (Koon et al., 2021; Santiago et al., 2022). Drowning represents a real public health problem, and data from the World Health Organization (2014) estimates that 42 persons die every hour from drowning. Furthermore, among infants and adults, drowning ranks as one of the top ten causes of death, and it is the third leading cause of unintentional death worldwide.

About 99.8% of lifeguards' working time is spent performing preventive actions, 0.1% is spent rescuing, and only 0.02% is spent providing medical care support (Szpilman et al., 2018). Although medical assistance is not a frequent task for lifeguards, some interventions require quick and effective action, such as providing support to victims in cardiac arrest and performing basic life support (BLS) (Vukmir, 2006). Without cardiopulmonary resuscitation (CPR) support, cardiac arrest victims will suffer initial brain damage within four minutes, while ten minutes may lead to severe or irreversible brain damage (Vilke et al., 2005). In the specific case of drowning, these injuries can occur with more severity, since this condition is caused by systemic hypoxemia (Hunn et al., 2020).

Cardiac arrest is defined as the cessation of proper contraction of the myocardium, leading to a loss of consciousness and absence of effective respiratory and cardiac function (Welbourn & Efstathiou, 2018). BLS has the potential to save the lives of individuals in cardiac arrest and other emergencies such as stroke, respiratory arrest, trauma, airway obstruction, or drowning (Moser & Coleman, 1992). Guidelines from the European Resuscitation Council suggest a BLS protocol of 30 compressions interspersed with 2 ventilations for adults, maintaining a rate of 100 to 120 compressions per minute, to keep blood circulating, to reverse the cardiac arrest scenario or augment the survival chances while waiting for defibrillation and advanced life support (Olasveengen, et al., 2021). It is also recommended to apply a compression depth of 50 to 60 mm in the center of the chest and provide a ventilatory tidal volume of 500 to 600 mL. Compressions play a crucial role in generating pressure, enabling the irrigation of the brain and other organs (Olasveengen et al., 2021). Ventilations are intended to deliver oxygen, remove carbon dioxide, and reduce the impedance of systemic perfusion. In victims of cardiac arrest due to drowning, ventilatory quality plays a critical role in increasing the survival chances (Queiroga et al., 2022).

Physical capacity is fundamental to executing demanding activities, such as the administration of BLS (Abraldes et al., 2020; Mooney et al. 2011). In opposition, fatigue (i.e., condition of exhaustion resulting from physical exertion) is a limiting factor of performance. When emergencies arise, lifeguards may perform an "all-out" physical exertion that may include swimming, running, and towing, attempting to rescue a victim, which will inevitably induce fatigue (Queiroga et al., 2014).

Professionals from various fields share the responsibility of performing BLS maneuvers, where an essential factor for their efficacy appears to be an adequate level of physical fitness, combined with regular training, prior experience, and advanced knowledge of the topic (Dainty & Gregory, 2017; Roshana et al., 2012). In the realm of lifeguarding, training courses are often of short duration, potentially limiting the depth of knowledge and experience that these professionals can acquire and retain (Bieliński & Jaśkiewicz, 2021). This combination of factors turns lifeguards into a group of professionals who may exhibit vulnerabilities in terms of their proficiency in providing CPR. Given the essential role of lifeguards in providing life-saving maneuvers, this review aims to compare lifeguards' CPR performance under conditions of rest and fatigue.

METHODS

PROTOCOL AND REGISTRATION

The study protocol was registered at the International Prospective Register of Systematic Reviews (PROSPERO) under the code CRD42022329221.

SEARCH STRATEGY: DATABASES

This study was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Page et al., 2021). The systematic literature search was conducted in the databases: PubMed, Web of Science, Academic Search Complete, and ScienceDirect, using the keywords: (lifeguard) AND ("cardiopulmonary" OR "cardiorespiratory" OR "basic life support" OR "resusc*").

SEARCH STRATEGY: ELIGIBILITY CRITERIA

All articles published until 25 May 2023 were considered for inclusion. After excluding articles by title and abstract, the second screening for inclusion of studies was conducted based on full-text analysis. This process was conducted by two investigators independently (FM, PS). To solve disagreements, a third author served as arbitrator (LS).

The screening of the articles met the following criteria, according to the PICOS approach:

Participants: Legally habilitated lifeguards.
Intervention: Administration of CPR under fatigue, on a solid surface, under simulated conditions.
Comparator: Administration of CPR under rest, on a solid surface, under simulated conditions.
Outcomes: Compression and ventilation quality.
Study Design: Quasi-experimental interventions.

QUALITY OF STUDIES AND RISK OF BIAS

The studies' overall methodological quality was assessed following the criteria of the JBI Critical Appraisal Tool for quasi-experimental studies (Munn et al., 2020). The scale consists of 10 items encompassing internal validity, risk of bias, adequate reporting of methods and results, and statistical analysis. The risk of bias across the studies was assessed using Egger's Regression test (Egger et al., 1997), by visually analyzing funnel plots and formal testing funnel plot asymmetries using the "trim and fill" algorithm (Duval & Tweedie, 2000).

DATA EXTRACTION AND ANALYSIS

General characteristics and results of the individual studies were extracted independently by two authors (FM, PS). A meta-analysis with a random-effects model was performed using restricted maximum-likelihood estimation, to examine the effects of physical fatigue on the quality of CPR compressions and ventilations. Summary effect sizes were presented for each study using standardized mean difference (SMD) to compare the effects between rested and fatigued conditions. Effect sizes are expressed as Hedges' g, to account for possible overestimation of the true population effect size in small studies. The magnitude of effect size was interpreted according to the following scale: <0.20 = negligible effect, 0.20 – 0.49 = small effect, 0.50 – 0.79 = moderate effect, ≥0.80 = large effect (Cohen, 1992). A *p*-value of 0.05 was considered statistically significant for all analyses, and a 95% confidence and prediction interval was assumed. Heterogeneity was assessed using the I^2 statistic, which describes the percentage of variability in effect estimates attributable to heterogeneity rather than chance (Higgins et al., 2019). I^2 values of 25%, 50%, and 75% can be considered to reflect small, moderate, and large degrees of heterogeneity (Higgins et al., 2003). When the studies presented a ratio between total and correct number of compressions/ventilations, a percentage value was extracted and used as the result.

RESULTS

SEARCH, SELECTION, AND INCLUSION OF PUBLICATIONS

The initial search identified 451 articles, which were exported to the citation manager software EndNote 20™ (Clarivate Analytics, Philadelphia, PA). Duplicate records were removed (n = 87), resulting in 364 articles. The titles of the remaining manuscripts were screened (excluding 326). From the 38 articles left, the analyses of the abstracts and full texts were performed. As shown in Figure 1, a total of 8 original studies (297 participants) were included in this review. All excluded articles did not match the inclusion criteria previously described.

QUALITY OF THE STUDIES INCLUDED

The quality of the 8 studies included in this review was assessed using the JBI Critical Appraisal Tool for quasi-experimental studies (Munn et al., 2020). As presented in Table 1, all articles adequately reported inclusion criteria, measured the condition in a standard, reliable way for all participants, clearly reported the outcomes in the results section, included an appropriate statistical analysis, and presented the relevant demographic information. Most of the studies (88%) adequately reported valid methods used for the identification of the condition for all participants and reported clinical information of the participants.

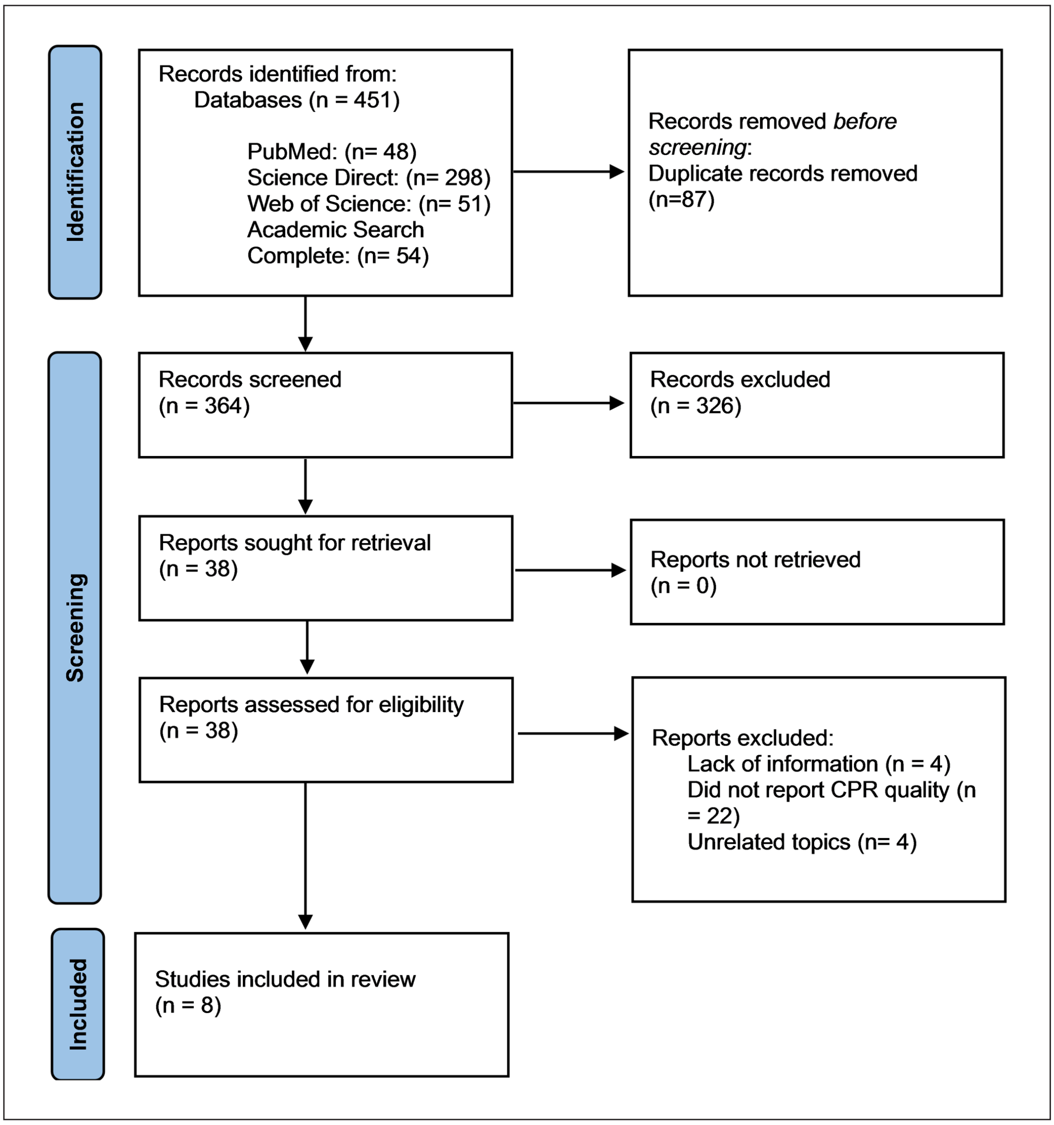

Figure 1 PRISMA Flow Diagram used for the article search.

	RUIBAL-LISTA ET AL. (2021)	LI ET AL. (2020)	BARCALA-FURELOS ET AL. (2020)	QUEIROGA ET AL. (2014)	BARCALA-FURELOS ET AL. (2014)	ABELAIRAS-GOMEZ ET AL. (2013)	BARCALA-FURELOS ET AL. (2013)	CLAESSON ET AL. (2011)
Were there clear criteria for inclusion in the case series?	✓	✓	✓	✓	✓	✓	✓	✓
Was the condition measured in a standard, reliable way for all participants included in the case series?	✓	✓	✓	✓	✓	✓	✓	✓
Were valid methods used for the identification of the condition for all participants included in the case series?	✓	?	✓	✓	✓	✓	✓	✓
Did the case series have consecutive inclusion of participants?	×	×	×	×	×	×	×	×
Did the case series have a complete inclusion of participants?	×	×	×	×	×	×	×	×
Was there clear reporting of the demographics of the participants included in the study?	✓	×	✓	×	✓	?	✓	✓
Was there clear reporting of clinical information of the participants?	×	✓	×	✓	✓	✓	✓	✓
Were the outcomes or follow-up results of cases clearly reported?	✓	✓	✓	✓	✓	✓	✓	✓
Was there clear reporting of the presenting sites'/clinics' demographic information?	✓	✓	✓	✓	✓	✓	✓	✓
Was statistical analysis appropriate?	✓	✓	✓	✓	✓	✓	✓	✓

Table 1 Studies' Quality According to JBI Critical Appraisal Tool (Munn et al., 2020).

✓ – Yes; × – No; ? – Unclear.

GENERAL DESCRIPTION OF THE STUDIES

CPR quality components included rate, depth, and ventilation to compression ratio. All eight included studies reported values related to chest compression quality, while seven reported results related to ventilations, as illustrated in Table 2. The synthesis of meta-analytical results is displayed in Table 3.

EFFECTS OF PHYSICAL FATIGUE ON CHEST COMPRESSIONS

During CPR, compressions constitute the most physically strenuous activity (Jones & Lee, 2008). From the included studies, seven comprised a swimming activity (Abelairas-Gomez et al., 2013; Barcala-Furelos et al., 2013; Barcala-Furelos et al., 2014; Claesson et al., 2011; Li et al., 2020; Queiroga et al., 2014; Ruibal-Lista et al., 2021), three included a running activity (Abelairas-Gomez et al., 2013; Barcala-Furelos et al., 2013; Barcala-Furelos et al., 2014), and one tested the performance of CPR under extreme heat conditions (Barcala-Furelos et al., 2020). We found a large and significant difference for compressions (Figure 2), favoring rested conditions (ES: –0.90). After the application of the trim and fill algorithm, the adjusted values remained equal to the observed.

AUTHORS	PARTICIPANTS/ COUNTRY	INTERVENTION	OUTCOMES
Ruibal-Lista et al. (2021)	10 (Males; age: 22.9 ± 2.4) Spain	2 min CPR 50 m swimming rescue + 2 min CPR 100 m swimming rescue + 2 min CPR	Both protocols reduced CPR quality. Compression quality was higher at the baseline measurement when compared to the performance after the exertion protocol (rest: 68.4%; 50 m: 51%; 100 m: 49.7%). Lifeguards have more consistently performed high-quality compressions vs ventilations, which often did not reach 50% of the required quality. Ventilations were the most negatively affected action associated with CPR.
Li et al. (2020)	14 (Males; age: 20 ± 0.7) China	2 min CPR 50 m swimming + 50 m swimming rescue + 10 min CPR performed by 1, 2 and 3 lifeguards	Fatigue generated through the exertion protocol did not significantly affect the CPR quality (95.57 ± 3.89 vs 89.0 ± 4.24). General lifeguards' CPR quality needs to be improved. The collaboration of two lifeguards was not superior to a single lifeguard on CPR quality.
Barcala-Furelos et al. (2020)	21 (14 males and 7 females; age: 27 ± 6) Spain	10 min CPR under normal temperature (25°C) and extreme heat (37°C)	Cardiopulmonary resuscitation performed under heat environments results in higher heart rate (71% vs 80%), and perceived effort (4 ± 2 vs 6 ± 2) and causes significant loss of fluids. No significant differences were found between environments for CPR quality when performed by two lifeguards.
Queiroga et al. (2014)	27 (23 males and 4 females; age: 21.3 ± 1.56) Spain	2 min CPR 25 m run + 25 m swimming + 25 m towing the victim + 2 min CPR	Rescue-related physical fatigue significantly increased the total number of chest compressions (137 ± 2 vs 151 ± 2.1) as well as the ratio of correct chest compressions (86.3 ± 3.8 vs 69.6 ± 6.3). Physical fatigue triggered by a swimming rescue negatively influenced general CPR quality. During the first minute of CPR, fatigue had a significant influence, both increasing the total number of compressions and reducing the percentage of correct chest compressions. Conversely, during the second minute fatigue had no significant effect on the quality of chest compressions.
Barcala-Furelos et al. (2014)	65 (51 males and 14 females; age: 22,.1 ± 2.96) Spain	5 min CPR 50 m running + 75 m swimming + 75 m dragging a manikin + 5 min CPR	CPR quality decreased significantly when the lifeguard was fatigued (295 ± 74 vs 283 ± 145). After the rescue, the lifeguard performs more incorrect compressions (83 ± 86 vs 131 ± 53). Both rested and fatigued groups presented similar results regarding ventilations, which were low.
Abelairas-Gomez et al. (2013)	60 (Age: 21.4 ± 1.55) Spain	4 min CPR 50 m running + 75 m swimming + 75 m swimming rescue + 4 min CPR	Physical fatigue negatively affects compressions and ventilation quality (57.8 ± 1.3 vs 54.2 ± 1.9). The number of correct compressions and ventilations gets reduced; however, the total number seems to increase.
Barcala-Furelos et al. (2013)	60 (Age: 21.4 ± 1.55) Spain	5 min CPR 50 m running + 75 m swimming + 75 m swimming rescue + 5 min CPR	Physical fatigue negatively influences CPR quality. The total of chest compressions (380 ± 4.99 vs 411 ± 7.24) and ventilations (24 ± 0.38 vs 26 ± 0.51) increases, however, the number performed with proper technique decreases (compressions: 285 ± 10.7 vs 246 ± 15.8; ventilations: 14 ± 0.91 vs 9 ± 0.86).
Claesson et al. (2011)	40 (26 males and 14 females; age range: 19 to 43) Sweden	10 min CPR 100 m swimming + 100 m swimming rescue + 10 min CPR	The quality of CPR was similar in rested and fatigued conditions. Half of the participants delivered continuous chest compressions in depth of >38 mm during 10 min of single-rescuer CPR.

Table 2 Characteristics of the Quasi-Experimental Studies Included in the Review.

m: meter; min: minutes; CPR: cardiopulmonary resuscitation; mm: millimetre.

OUTCOME	K (n)	SMD (95% CI)	95% PI	*p-VALUE*	STD. ERROR	I^2
Compressions quality	8 (297)	−0.90 (−1.35; -0.46)	−2.40; 0.59	<.001	0.23	84%
Ventilations quality	7 (257)	−1.10 (−2.23;0.02)	−5.19; 2.98	0.054	0.57	96.8%

Table 3 Meta-Analysis Summary.

K: number of studies; (n): number of participants; SMD: Standardized mean difference (Hedges' g); CI: Confidence Interval; PI: Prediction Interval; Std. Error: Standard Error; I^2- I^2 statistic.

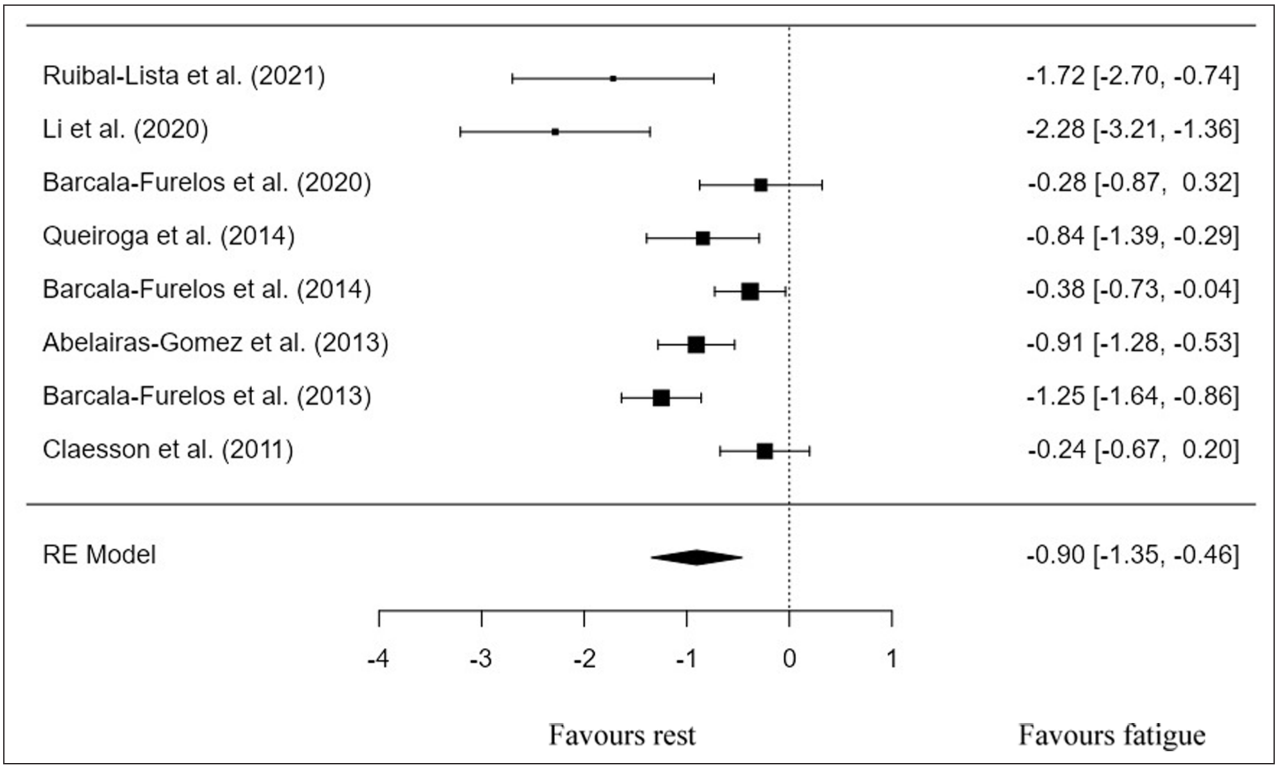

Figure 2 Forest Plot Illustrating the Effect of Physical Fatigue on the Quality of Compression.

EFFECTS OF PHYSICAL FATIGUE ON VENTILATION QUALITY

Ventilations are a fundamental part of successful resuscitation, especially for drowning victims (Løfgren & Beerman, 2014; Wnent et al., 2021). It is suggested that a duration of one second per ventilation at a rate of eight to ten per minute, for adults is effective (Olasveengen, et al., 2021). Seven studies included measures of ventilation quality during CPR. A large non-significant effect was found for ventilation (Figure 3), favoring rest conditions (ES: −1.10). After the application of the trim and fill algorithm, the adjusted values remained equal to the observed.

DISCUSSION

Cardiopulmonary resuscitation quality can be decisive to save individuals in life-threatening emergencies (Abella, 2016; Szpilman et al., 2018). For lifeguards, the application of these maneuvers may be preceded by a fatiguing activity (e.g., water rescue). In this sense, understanding how physical fatigue can impact resuscitation is a determinant of understanding how these professionals should be prepared.

All studies have reported a detrimental effect on compression quality while fatigued. Despite the decreased number of correct compressions, lifeguards performed a higher total number of chest compressions in fatigue. This may be resultant of higher heart rates, associated with the rescue preceding basic life support, which was found to be similar to those expected at a moderate intensity physical activity (60–70% of maximum intensity) (Abraldes et al., 2020; Ruibal-Lista et al., 2021). Moreover, most of the time, a higher rate of compressions, resulted in lower CPR quality scores (Li et al., 2020; Queiroga et al., 2014). Also, when performed continuously, the depth of compressions is lowered, which may be due to a loss of applied force, caused by physical fatigue, or a consequence of not allowing the chest to properly expand after each compression (Dainty & Gregory, 2017). In this regard, it has been suggested that a 4-week strength training program can positively affect the maintenance of CPR quality over ten minutes (Abelairas-Gomez et al., 2017).

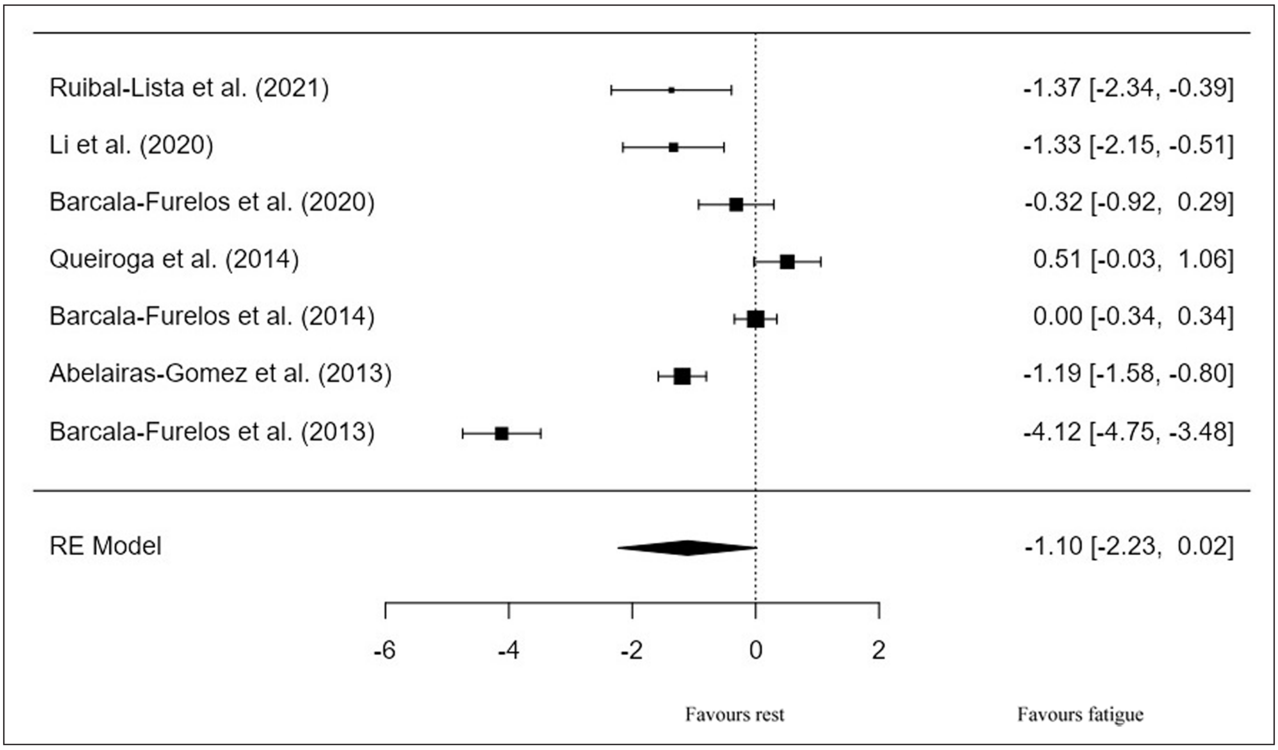

Figure 3 Forest Plot Illustrating the Effects of Physical Fatigue on the Quality of Ventilation.

Quality chest compressions are fundamental to increasing survival from cardiac arrest, as they move blood through the brain. If chest compression quality is low, the survival chances would also be lower (Georgiou et al., 2014). This only strengthens the need to keep lifeguards regularly trained, so they can maintain high CPR performances. The results for ventilations were more heterogeneous, with studies reporting advantages (Queiroga et al., 2014), neutral effects (Barcala-Furelos et al., 2014), or detriments caused by physical fatigue (Abelairas-Gomez et al., 2013; Barcala-Furelos et al., 2013; Ruibal-Lista et al., 2021). The amount of air expelled by a lifeguard and respiratory rate might have affected ventilatory quality, which was revealed to be generally poor (Li et al., 2020). As ventilatory quality is not as dependent on physical capacity as compressions, this factor may assist in explaining the results obtained.

Lifeguards would probably benefit from regular CPR training programs, similar to those tested with other healthcare professionals, such as nurses or paramedics (Anderson et al., 2019; Govender et al., 2016; Mokhtari Nori et al., 2012). A study by Aranda García et al., (2022) reported that new lifeguards achieve higher performances in all CPR domains compared to those more experienced, which may be a result of the lack of regular training. This variable, alongside proper feedback from an experienced professional or from manikins that use software to assess CPR quality, may be a determinant factor contributing to achieving higher performances during BLS (Bleijenberg et al., 2017; Chamberlain et al., 2002; Dainty & Gregory, 2017).

LIMITATIONS

The quality of studies included was fair to good, according to the results of the critical appraisal checklist. From the 10 points, all studies ranged from 6 to 8. The results of this work illustrate that physical fatigue induces negative effects on the administration of CPR by lifeguards. There are, however, some limitations that should be acknowledged. Firstly, the fact that all trials were performed under simulated conditions may have influenced the results obtained. In realistic conditions, anxiety and adrenaline would play a role and potentially dictate different outcomes (Chang et al., 2020). Secondly, lifeguards' gender, cardiorespiratory fitness, and strength were not considered. In this regard, the overall physical capacity of lifeguards and their gender may play a determining role in both rescue time and the maintenance of CPR quality (Sousa et al., 2017), therefore, it is expected that some individuals are more trained than others. Likewise, the different nature of simulated rescues and subsequent CPR time performed by lifeguards may impact the results, with higher levels of fatigue probably being associated with lower CPR quality (Sousa et al., 2019). Thirdly, considering the reduced number of studies and participants, at this point, it is uncertain that these results represent the effects of physical fatigue on lifeguards' CPR with absolute precision. Moreover, different countries have different requirements to qualify lifeguards, and therefore the baseline training and experience might not be comparable and can bias our results. The exclusion of non-English or non-Spanish sources may have limited the number of studies in this review. In this sense, caution should be exercised when interpreting these results.

Future research recommendations

We suggest that future studies explore the possibility of categorizing CPR quality based on gender, cardiorespiratory fitness levels, and the physical strength of lifeguards, which could potentially yield valuable insights. It would also be worthwhile to investigate the effectiveness of various training programs, considering factors such as program duration and methodology, to determine which approaches yield the best results.

Additionally, it might be beneficial to explore the psychological impact of real rescue attempts and resuscitation maneuvers on individuals, even when they have undergone emotional training for such situations, as there could be potential traumatic effects (Swanson, 1993).

CONCLUSIONS

To our knowledge, this is the first systematic review assessing the effects of physical fatigue on lifeguards' CPR performance. This study highlights that physical fatigue plays a detrimental role in lifeguards' ability to perform high-quality CPR, both for compressions and ventilations.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Filipe Maia orcid.org/0000-0002-4026-3804
Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD), University of Maia, Maia, Portugal

Luis Sousa orcid.org/0000-0002-3366-1118
N2i, Polytechnic Institute of Maia, Maia, Porto, Portugal

Paulo Santiago orcid.org/0000-0002-6060-6667
N2i, Polytechnic Institute of Maia, Maia, Porto, Portugal

REFERENCES

Abelairas-Gomez, C., Barcala-Furelos, R., Szarpak, L., Garcia-Garcia, O., Paz-Dominguez, A., Lopez-Garcia, S., & **Rodriguez-Nunez, A.** (2017). The effect of strength training on quality of prolonged basic cardiopulmonary resuscitation. *Kardiologia Polska*, *75*(1), 21–27. DOI: https://doi.org/10.5603/KP.a2016.0165

Abelairas-Gomez, C., Perez, V. R., Furelos, R. B., & **Aguilar, J. P.** (2013). Effect of lifeguard fatigue on the first 4 minutes of cardiopulmonary resuscitation after water rescue. *Emergencias*, *25*(3), 184–190.

Abella, B. S. (2016). High-quality cardiopulmonary resuscitation: current and future directions. *Curr Opin Crit Care*, *22*(3), 218–224. DOI: https://doi.org/10.1097/MCC.0000000000000296

Abraldes, J. A., Fernandes, R. J., Rodríguez, N., & **Sousa, A.** (2020). Is rescuer cardiopulmonary resuscitation jeopardized by previous fatiguing exercise? *International Journal of Environmental Research and Public Health*, *17*(18), 1–11. DOI: https://doi.org/10.3390/ijerph17186668

Anderson, R., Sebaldt, A., Lin, Y., & **Cheng, A.** (2019). Optimal training frequency for acquisition and retention of high-quality CPR skills: A randomized trial. *Resuscitation*, *135*, 153–161. DOI: https://doi.org/10.1016/j.resuscitation.2018.10.033

Aranda García, S., Carballo Fazanes, A., Otero Agra, M., Fernández Méndez, M., Barcala Furelos, M., & **Barcala Furelos, R.** (2022). Comparación de la calidad en la ventilación de socorristas nóveles y veteranos. Un estudio piloto de simulación. *Revista de Investigación en Actividades Acuáticas*, *6*(11), 37–43. DOI: https://doi.org/10.21134/riaa.v6i11.1646

Barcala-Furelos, R., Abelairas-Gomez, C., Romo-Perez, V., & **Palacios-Aguilar, J.** (2013). Effect of physical fatigue on the quality CPR: A water rescue study of lifeguards: Physical fatigue and quality CPR in a water rescue. *The American Journal of Emergency Medicine*, *31*(3), 473–477. DOI: https://doi.org/10.1016/j.ajem.2012.09.012

Barcala-Furelos, R., Abelairas-Gomez, C., Romo-Perez, V., & **Palacios-Aguilar, J.** (2014). Influence of automatic compression device and water rescue equipment in quality lifesaving and cardiopulmonary resuscitation. *Hong Kong Journal of Emergency Medicine*, *21*(5), 291–299. DOI: https://doi.org/10.1177/102490791402100503

Barcala-Furelos, R., Fernández-Méndez, M., Cano-Noguera, F., Otero-Agra, M., Morán-Navarro, R., & **Martínez-Isasi, S.** (2020). Measuring the physiological impact of extreme heat on lifeguards during cardiopulmonary resuscitation. Randomized simulation study. *The American Journal of Emergency Medicine*, *38*(10), 2019–2027. DOI: https://doi.org/10.1016/j.ajem.2020.06.042

Bieliński, J. R., & **Jaśkiewicz, F.** (2021). Lifeguards' Knowledge retention following airway management, ventilation, and oxygen administration training. *Emergency Medical Service*, *8*(4), 225–231. DOI: https://doi.org/10.36740/EmeMS202104104

Bleijenberg, E., Koster, R. W., De Vries, H., & **Beesems, S. G.** (2017). The impact of post-resuscitation feedback for paramedics on the quality of cardiopulmonary resuscitation. *Resuscitation*, *110*, 1–5. DOI: https://doi.org/10.1016/j.resuscitation.2016.08.034

Chamberlain, D., Smith, A., Woollard, M., Colquhoun, M., Handley, A., Leaves, S., & **Kern, K.** (2002). Trials of teaching methods in BLS (3): comparison of simulated CPR performance after first training and at 6 months, with a note on the value of re-training. *Resuscitation*, *53*(2), 179–187. DOI: https://doi.org/10.1016/S0300-9572(02)00025-4

Chang, C., Putukian, M., Aerni, G., Diamond, A., Hong, G., Ingram, Y., Reardon, C. L., & **Wolanin, A.** (2020). Mental health issues and psychological factors in athletes: detection, management, effect on performance and prevention: American Medical Society for Sports Medicine Position Statement—Executive Summary. *British Journal of Sports Medicine*, *54*(4), 216–220. DOI: https://doi.org/10.1136/bjsports-2019-101583

Claesson, A., Karlsson, T., Thorén, A.-B., & **Herlitz, J.** (2011). Delay and performance of cardiopulmonary resuscitation in surf lifeguards after simulated cardiac arrest due to drowning. *The American Journal of Emergency Medicine*, *29*(9), 1044–1050. DOI: https://doi.org/10.1016/j.ajem.2010.06.026

Cohen, J. (1992). A power primer. *Psychological bulletin*, *112*(1), 155. DOI: https://doi.org/10.1037//0033-2909.112.1.155

Dainty, R. S., & **Gregory, D. E.** (2017). Investigation of low back and shoulder demand during cardiopulmonary resuscitation. *Applied Ergonomics*, *58*, 535–542. DOI: https://doi.org/10.1016/j.apergo.2016.04.013

Duval, S., & **Tweedie, R.** (2000). Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*, *56*(2), 455–463. DOI: https://doi.org/10.1111/j.0006-341X.2000.00455.x

Egger, M., Smith, G., Schneider, M., & **Minder, C.** (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ*, *315*(7109), 629–634. DOI: https://doi.org/10.1136/bmj.315.7109.629

Georgiou, M., Papathanassoglou, E., & **Xanthos, T.** (2014). Systematic review of the mechanisms driving effective blood flow during adult CPR. *Resuscitation*, *85*(11), 1586–1593. DOI: https://doi.org/10.1016/j.resuscitation.2014.08.032

Govender, K., Sliwa, K., Wallis, L., & **Pillay, Y.** (2016). Comparison of two training programmes on paramedic-delivered CPR performance. *Emergency Medicine Journal*, *33*(5), 351–356. DOI: https://doi.org/10.1136/emermed-2014-204404

Higgins, J. P., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & **Welch, V. A.** (2019). *Cochrane handbook for systematic reviews of interventions*. John Wiley & Sons. DOI: https://doi.org/10.1002/9781119536604

Higgins, J. P., Thompson, S. G., Deeks, J. J., & **Altman, D. G.** (2003). Measuring inconsistency in meta-analyses. *BMJ*, *327*(7414), 557–560. DOI: https://doi.org/10.1136/bmj.327.7414.557

Hunn, E. S., Helmer, S. D., Reyes, J., & **Haan, J. M.** (2020). Patterns of injuries in drowning patients – Do these patients need a trauma team? *Kansas Journal of Medicine*, *13*, 165–178. DOI: https://doi.org/10.17161/kjm.v13i.13871

Jones, A. Y., & **Lee, R. Y.** (2008). Rescuer's position and energy consumption, spinal kinetics, and effectiveness of simulated cardiac compression. *American Journal of Critical Care*, *17*(5), 417–425; discussion 426–417. DOI: https://doi.org/10.4037/ajcc2008.17.5.417

Koon, W., Schmidt, A., Queiroga, A. C., Sempsrott, J., Szpilman, D., Webber, J., & **Brander, R.** (2021). Need for consistent beach lifeguard data collection: results from an international survey. *Injury Prevention*, *27*(4), 308–315. DOI: https://doi.org/10.1136/injuryprev-2020-043793

Li, S., Kan, T., Guo, Z. J., Chen, C. L., & **Gui, L.** (2020). Assessing the quality of CPR performed by a single lifeguard, two lifeguards and a lifeguard with a bystander after water rescue: a quasi-experimental trial. *Emergency Medicine Journal*, *37*(5), 306–313. DOI: https://doi.org/10.1136/emermed-2018-207939

Løfgren, B., & **Beerman, S.** (2014). Automated external defibrillators in the aquatic environment. In J. J. L. M. Bierens (Ed.), *Drowning: Prevention, Rescue, Treatment* (pp. 601–606). Springer Berlin Heidelberg. DOI: https://doi.org/10.1007/978-3-642-04253-9_93

Mokhtari Nori, J., Saghafinia, M., Kalantar Motamedi, M. H., & **Khademol Hosseini, S. M.** (2012). CPR training for nurses: how often is it necessary? *Iranian Red Crescent Medical Journal*, *14*(2), 104–107.

Mooney, M., O'Brien, B., Cormack, S., Coutts, A., Berry, J., & **Young, W.** (2011). The relationship between physical capacity and match performance in elite Australian football: a mediation approach. *Journal of Science and Medicine in Sport*, *14*(5), 447–452. DOI: https://doi.org/10.1016/j.jsams.2011.03.010

Moser, D. K., & **Coleman, S.** (1992). Recommendations for improving cardiopulmonary resuscitation skills retention. *Heart Lung*, *21*(4), 372–380.

Munn, Z., Barker, T. H., Moola, S., Tufanaru, C., Stern, C., McArthur, A., Stephenson, M., & **Aromataris, E.** (2020). Methodological quality of case series studies: an introduction to the JBI critical appraisal tool. *JBI evidence synthesis*, *18*(10), 2127–2133. DOI: https://doi.org/10.11124/JBISRIR-D-19-00099

Olasveengen, T. M., Semeraro, F., Ristagno, G., Castren, M., Handley, A., Kuzovlev, A., Monsieurs, K. G., Raffay, V., Smyth, M., Soar, J., Svavarsdottir, H., & **Perkins, G. D.** (2021). European Resuscitation Council Guidelines 2021: Basic Life Support. Resuscitation, *161*, 98–114. DOI: https://doi.org/10.1016/j.resuscitation.2021.02.009

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ (Clinical research ed.), 372*, n71. DOI: https://doi.org/10.1136/bmj.n71

Queiroga, A. C., Barcala-Furelos, R., Abelairas-Gomez, C., & **GarcÍA-SoidÁN, J. L.** (2014). CPR quality reduced due to physical fatigue after a water rescue in a swimming pool. *Signa Vitae*, *9*(2), 25–31. DOI: https://doi.org/10.22514/SV92.112014.4

Queiroga, A. C., Dunne, C., Manino, L. A., Van Der Linden, T., Mecrow, T., & **Bierens, J.** (2022). Resuscitation of drowned persons during the COVID-19 pandemic. *JAMA Network Open*, *5*(2). DOI: https://doi.org/10.1001/jamanetworkopen.2021.47078

Roshana, S., Kh, B., Rm, P., & **Mw, S.** (2012). Basic life support: knowledge and attitude of medical/paramedical professionals. *World Journal of Emergency Medicine*, *3*(2), 141. DOI: https://doi.org/10.5847/wjem.j.issn.1920-8642.2012.02.011

Ruibal-Lista, B., Moral-García, J. E., & **López-García, S.** (2021). Relationship between rescue distance and the quality of simulated CPR: a pilot study with lifeguards. *Signa Vitae*, *17*(3), 137–143. DOI: https://doi.org/10.22514/sv.2021.044

Santiago, P., Maia, F., Santiago, S., Duarte, D., & **Teques, P.** (2022). Lifeguard performance skills: a systematic review. *International Journal of Aquatic Research and Education*, *13*(4), 1–11. DOI: https://doi.org/10.25035/ijare.13.04.05

Sousa, A., Fernandes, R. J., Rodríguez, N., & **Abraldes, J. A.** (2017). Influence of a 100-M simulated in-water rescue on cardiopulmonary parameters. *Prehospital Emergency Care*, *21*(3), 301–308. DOI: https://doi.org/10.1080/10903127.2016.1254695

Sousa, A., Ribeiro, J., & **Figueiredo, P.** (2019). Physiological demands in sports practice. *The Sports Medicine Physician* (pp. 37–44). Springer. DOI: https://doi.org/10.1007/978-3-030-10433-7_4

Swanson, R. W. (1993). Psychological issues in CPR. *Annals Emergency Medicine*, *22*(2), 350–353. DOI: https://doi.org/10.1016/S0196-0644(05)80464-0

Szpilman, D., Oliveira, R., Mocellin, O., & **Webber, J.** (2018). Is drowning a mere matter of resuscitation? *Resuscitation*, *129*, 103–106. DOI: https://doi.org/10.1016/j.resuscitation.2018.06.018

Vilke, G. M., Chan, T. C., Dunford, J. V., Metz, M., Ochs, G., Smith, A., Fisher, R., Poste, J. C., McCallum-Brown, L., & **Davis, D. P.** (2005). The three-phase model of cardiac arrest as applied to ventricular fibrillation in a large, urban emergency medical services system. *Resuscitation*, *64*(3), 341–346. DOI: https://doi.org/10.1016/j.resuscitation.2004.09.011

Vukmir, R. B. (2006). Survival from prehospital cardiac arrest is critically dependent upon response time. *Resuscitation*, *69*(2), 229–234. DOI: https://doi.org/10.1016/j.resuscitation.2005.08.014

Welbourn, C., & **Efstathiou, N.** (2018). How does the length of cardiopulmonary resuscitation affect brain damage in patients surviving cardiac arrest? A systematic review. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *26*(1). DOI: https://doi.org/10.1186/s13049-018-0476-3

Wnent, J., Tjelmeland, I., Lefering, R., Koster, R. W., Maurer, H., Masterson, S., Herlitz, J., Böttiger, B. W., Ortiz, F. R., Perkins, G. D., Bossaert, L., Moertl, M., Mols, P., Hadžibegović, I., Truhlář, A., Salo, A., Baert, V., Nagy, E., Cebula, G., … Radstok, A. (2021). To ventilate or not to ventilate during bystander CPR- A Eureca two analysis. *Resuscitation*, *166*, 101–109. DOI: https://doi.org/10.1016/j.resuscitation.2021.06.006

World Health Organization. (2014). *Global Report On Drowning* (9789241564786).

TO CITE THIS ARTICLE:
Maia, F., Sousa, L., & Santiago, P. (2023). Effects of Physical Fatigue on Cardiopulmonary Resuscitation Quality by Lifeguards: A Systematic Review and Meta-analysis. *International Journal of First Aid Education*, *6*(1), 70–80. DOI: https://doi.org/10.25894/ijfae.6.1.91

Submitted: 15 June 2023 **Accepted:** 19 October 2023 **Published:** 03 November 2023

International Journal of First Aid Education is a peer-reviewed open access journal published by Aperio.

aperio