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REVIEW | REVISÃO

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Impact of compression surfaces on cardiac massage during cardiopulmonary reanimation: an integrative review

Impacto das superfícies de compressão na massagem cardíaca durante a reanimação cardiopulmonar: uma revisão integrativa

Impacto de las superficies de compresión en el masaje cardíaco durante la reanimación cardiopulmonar: una revisión integrativa

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Abstract

Objective: To synthesize the available evidence in the literature on the types of compression surfaces used in CPR and to analyze which characteristics of the compression surfaces impact the effectiveness of chest compression during CPR. **Method**: Integrative literature review, whose selection and inclusion criteria were complete articles, in English, Portuguese or Spanish and that answered the following research question: "What are the characteristics of the compression surfaces that impact the effectiveness of chest compressions during CPR?". It was carried out between June and July 2019. **Results**: 12 articles from experimental studies were included. 13 different types of mattresses were found. Regarding the boards, six different sizes and many materials were reported. Influences of the type of compression surface on the force required to perform chest compressions were found. **Conclusion:** Evidence points out that larger mattresses with pressure reduction technology and larger beds have negative impacts on the quality of chest compressions. **Implication for practice:** Knowledge about the influence of the type and characteristics of support surfaces on the quality of chest compressions can support professionals in the choice and incorporation of technologies in the hospital environment.

Keywords: Cardiopulmonary Resuscitation; Cardiac Massage; Cardiac Arrest; Advanced Cardiac Vital Support; Review.

Resumo

Objetivo: sintetizar as evidências disponíveis na literatura sobre os tipos de superfícies de compressão utilizadas na RCP e analisar quais características das superfícies de compressão têm impacto na eficácia da compressão torácica durante a RCP. **Método:** revisão integrativa da literatura, cujos critérios de seleção e inclusão foram: artigos completos, em inglês, português ou espanhol e que respondessem a seguinte questão de pesquisa: "Quais são as características das superfícies de compressão que têm impacto na eficácia das compressões torácicas durante a RCP?". Realizada entre os meses de junho e julho de 2019. **Resultados:** inclui-se 12 artigos de estudos experimentais, cuja extração de dados revelou 13 tipos diferentes de colchões. Em relação às pranchas, seis tamanhos diferentes foram relatados, com diferentes materiais. Constatou-se influências do tipo de superfície de compressão na força necessária para realizar as compressões torácicas. **Conclusão:** as evidências apontam que colchões de maiores dimensões e com tecnologia para redução de pressão e camas mais largas apresentam impactos negativos na qualidade das compressões torácicas. **Implicação para prática:** o conhecimento sobre a influência do tipo e características das superfícies de apoio na qualidade das compressões torácicas podem subsidiar profissionais na escolha e incorporação de tecnologias no ambiente hospitalar.

Palavras-chave: Reanimação Cardiopulmonar; Massagem Cardíaca; Parada Cardíaca; Suporte Vital Cardíaco Avançado; Revisão.

Resumen

Objetivo: Sintetizar la evidencia disponible en la literatura sobre los tipos de superficies de compresión utilizadas en la RCP y analizar qué características de las superficies de compresión tienen un impacto en la efectividad de la compresión torácica durante la RCP. **Método:** Revisión bibliográfica integradora, cuyos criterios de selección e inclusión fueron: artículos completos, en inglés, portugués o español y que respondieran a la siguiente pregunta de investigación: "¿Cuáles son las características de las superficies de compresión que inciden en la efectividad de las compresiones torácicas durante la RCP?". Se llevó a cabo entre junio y julio de 2019. **Resultados:** se incluyeron 12 artículos de estudios experimentales, cuya extracción de datos reveló 13 tipos diferentes de colchones. En cuanto a los tableros, se reportaron seis tamaños diferentes, con diferentes materiales. Se encontraron influencias del tipo de superficie de compresión sobre la fuerza requerida para realizar las compresiones torácicas. **Conclusión:** la evidencia señala que los colchones más grandes con tecnología de reducción de presión y las camas más grandes tienen impactos negativos en la calidad de las compresiones torácicas. **Implicación para la práctica:** El conocimiento sobre la influencia del tipo y características de las superficies de apoyo en la calidad de las compresiones torácicas puede ayudar a los profesionales en la elección e incorporación de tecnologías en el ámbito hospitalario.

Palabras clave: Reanimación Cardiopulmonar; Masaje Cardíaco; Paro Cardíaco; Soporte Vital Cardíaco Avanzado; Revisión.

INTRODUCTION

Thoracic compression is one strategy that makes up the set of actions required for cardiopulmonary resuscitation (CPR). Variables such as initial cardiopulmonary arrest (CPA) rhythm, training of the professionals involved in care, available technologies, and human and material resources are known to interfere in the success of CPR[1-3]. Among these materials, compression surfaces such as bed, stretcher, mattress, and surface (backboard) where the patient is supported are highlighted in this article[4].

Compression surfaces need to contribute to a high-quality cardiac massage[5], that is to say, that which reaches a depth of between 5 cm and 6 cm, a frequency of 100 to 120 compressions per minute, and complete return of the chest[3,5]. However, some studies show that, in practice, the quality of chest compressions does not meet these recommendations, even in trained and often CPA-exposed teams, which contributes to low success in resuscitation[6] evidenced by the survival rate after intra-hospital CPA being less than 20%[3].

In favor of optimizing the efficacy of the compressions, recommendations for increasing CPR quality include minimizing the interruption time of the chest compressions during CPA care and positioning the victims in the supine position on a firm compression surface (floor or backboards) [1]. However, the American Heart Association recognizes a weak evidence base for this recommendation and, in addition to that, there is a lack of guidelines regarding the specificities of performing CPR maneuvers in hospital conditions, where the patients are bedridden[1].

It is noted that the variables linked to the compression surface, such as the size of the product, the material used, and densities, can exert an impact on the range of the appropriate depth in chest compression, increasing the force required to deform the thorax, which is proportional to the displacement generated by the surfaces. In an exploratory search carried out on the websites of the main suppliers of backboards available in the national and international markets, surfaces with very different characteristics were identified, varying in thickness (from 0.5 cm to 9.0 cm), length (40 cm to 100 cm), width (35 cm to 60 cm) and materials (polyethylene, acrylic, wood, medium density fiber board-MDF, and plastic).

Several studies showed a possible reduction in the efficacy of chest compressions during advanced cardiac life support due to the soft surfaces of hospital beds; this is because, when performing compressions on bedridden patients, the mattress undergoes deflection concomitantly with the patient's chest, precluding adequate chest compression[7-10].

Although compression surfaces are widely used in clinical practice, there are no guidelines on their ideal characteristics, which results in variability of materials available in intra-hospital environments. In addition, the latest published updates of the American Heart Association[11-13] guidelines for basic and advanced life support do not mention compression surfaces, the approach to this theme being restricted to the guideline published in 2015[1], aspects that evidence the relevance of this research, justifying its conduction.

OBJECTIVE

To synthesize the evidence available in the literature on the types of compression surfaces used in CPR and to analyze which characteristics of the compression surfaces exert an impact on the efficacy of chest compression during CPR.

METHOD

Study design, period and locus

The authors made an integrative review study with the support of the PRISMA tool between June and July 2019. The review followed these methodological stages: formulation of the research question; establishment of the criteria to search for primary studies; data organization; analysis and discussion of the results; and presentation of the review[14].

The search for primary studies was conducted in six online access virtual databases, as follows: *Banco de Dados em Enfermagem* (BDENF) – via BVS; Cumulative Index to Nursing and Allied Health Literature (CINAHL) – via EBSCO; Índice *Bibliográfico Espanhol de Ciências de Saúde* (INECS) – via BVS; *Literatura Latino-Americana em Ciências de Saúde* (LILACS) – via BVS; and Medical Literature Analysis and Retrieval System Online (Medline) – via PubMed and Scopus.

The research question "What are the characteristics of compression surfaces that exert an impact on the efficacy of chest compressions during CPR?", which guided this search, was constructed with the aid of the PVO strategy (Problem, Variable and Outcome)[15], delimited as follows in the study: Problem: Chest Compressions; Variable: Compression surface; and Outcome*:* Efficacy of chest compression.

Sample; inclusion and exclusion criteria

Scientific articles selected based on the inclusion criteria were used, namely: in a full-text format available in the selected databases, in Portuguese, English, and Spanish and which were related to the research question regarding any of its elements (problem, variable or outcome). No limited time frame was established in literature searching because the absence of the apparent national and international recommendation about the compression surface to support the patient during CPR. Then, many studies as possible were included to a global understanding of the phenomenon, by synthesis. Articles whose contents were considered unsatisfactory in answering the research question were excluded, a classification based on the analysis of the relevance of their contribution in understanding the object of this review.

Study protocol

Two reviewers independently searched in literature, and the disagreements were resolved by consensus among peers or by the evaluation of a third reviewer when disagreement was maintained. The descriptors and keywords were chosen concerning the research question. Consequently, the descriptors were defined from the DeCS and Mesh Terms, using the following terms: "*heart* *massage"* (problem); "*cardiopulmonary resuscitation"* (outcome), in addition to using the keyword "*backboards"* (variable). These research terms were gathered and organized using the Boolean operator *AND*, adapted according to each source of information consulted. Chart 1 shows the search strategies used in this review, according to the specificities of each database.

Exploratory, selective and analytical reading was used for selecting the articles. The exploratory reading of titles and abstracts judged compliance with the inclusion criteria. In the selective reading phase, the complete text of article was read and it was evaluated whether the studies were related to the research question regarding any of its elements (problem, variable or outcome). In the last phase, the pre-selected studies were read again in full, listing the key ideas, with evaluation of the content as to the relevance of its contribution in understanding the phenomenon under study.

Data extraction from the selected primary studies was conducted with the aid of an instrument elaborated by the authors themselves. For each study included, the following information was captured: general characteristics of the study (identification, locus institution, type of publication), objective and population, manikins and surfaces, type of study and results related to the characteristics of compression surfaces and their impact on chest compressions.

Analysis of results and statistics

The information collected was later organized, in the light of the research question, in view of the knowledge synthesis. In this sense, the data from the articles were classified according to the type of compression surface (bed, mattress, backboard and stretcher) and their physical characteristics. From this classification, the data from the articles were summarized. For the synthesis of the physical characteristics, the dimensions of the surfaces were analyzed based on the application of descriptive statistics

Chart 1. Search strategies used in each database. Rio de Janeiro, RJ, Brazil, 2021.

Descriptors	
Database	Boolean phrase
IBECS; BDENF; LILACS (Via BVS)	("*Massagem Cardíaca*") AND ("*Reanimação Cardiopulmonar*")
Medline/Pubmed	(("*heart massage*") AND ("*cardiopulmonary resuscitation*")) AND (*backboards*)
SCOPUS	(TITLE-ABS-KEY ("*heart massage*") AND TITLE-ABS-KEY ("*cardiopulmonary resuscitation*") AND TITLE-ABS-KEY (*backboards*))
CINAHL	(("*heart massage*") AND ("*cardiopulmonary resuscitation*")) AND (*backboards*)

with simple and percentage frequency and measures of central tendency. Regarding the data related to the type of surface and impact on the efficacy of chest compression, at the end of the summary stage it was possible to visualize the data set, from which aggregation of evidence and its interpretation were performed for the knowledge synthesis and for understanding the phenomenon under study.

The final result of the review was first organized by presenting a chart with the main information of the corpus of articles, followed by analyzing the results that express the aggregation of evidence and knowledge synthesis. The studies were coded employing the letter E, followed by the Arabic number that indicates the presentation order.

RESULTS

The database searches resulted in 189 documents. After removing the duplicates, 187 articles remained, of which 156 were excluded in the application stage of the eligibility criteria from the reading of titles and abstracts. 19 studies were excluded from the reading of the full texts, in selective and analytical readings. Thus, 12 studies comprised the final sample of the review. The study search and selection process is graphically represented as a flowchart in Figure 1.

All the studies included in this review were published from 2006 to 2016, in English, and were mainly produced in Korea (n=3; 25.0%) and South Africa (n=2; 16.7%). Of the total number of analyzed studies, seven were published in American journals specialized in Emergency and Resuscitation. Most of the studies were produced by professionals who were based in universities (n=7; 58.4%). As for the methodological design, all the studies were experimental and mostly used the Resusci Anne Modular System Skill Reporter Laerdal® manikin (n=5; 41.9%). As for the performer of the chest compressions, human performers predominated (n=10; 80%), with automatic compressors representing the minority (n=2; 20%).

Regarding the compression surfaces that were evaluated in the experiments, five (41.7%) studies combined bed and mattress (E5, E6, E7, E9, E10); three (25.0%) combined stretcher and mattress (E2, E3, E11); two (16.7%) combined stretcher or bed and mattress (E1 and E12); one (8.3%) used only the floor (E8) and one (8.3%) used only the mattress (E4). Regarding the use of backboards, nine (75%) studies pointed out their use (E3, E5, E6, E7, E8, E9, E10, E11, E12). The main data from the studies included in the corpus of this review were organized in Chart 2.

The synthesis elaborated after aggregating the results in the selected research studies indicated that the current knowledge on the compression surfaces is organized into two synthesis units: typology and characterization of the compression surfaces and impact of the surfaces on the quality of chest compressions.

Concerning typology and characterization of the compression surfaces, 13 different types of mattresses were used in the studies. The majority was made of foam (38.4%); however, 38.4% did not describe the material the mattress was made of. Of the studies that used a bed or stretcher without a mattress as compression

Chart 2. Synopsis of the articles included in the integrative review. Rio de Janeiro, RJ, Brazil, 2020.

Title, journal, country, language, year and researchers' locus	Objectives	Type of study Thoracic compressions performer Experiments' manikins and surfaces	Impact of the surfaces on the Chest compressions
E1 - Effect of bed width on the quality of compressions in simulated resuscitation: a randomized crossover manikin study [16] American Journal of Emergency Medicine. China. English, 2016. University Hospital.	To investigate the effects of bed width on the quality of chest compressions during resuscitation.	Randomized crossover study with a manikin Human performer (97 fourth-year medical students) **Manikin:** Resusci Anne QCPR **Bed:** PARAMOUNT BED®, 940 mm × 2,180 mm, PARAMOUNT Co BED **Stretcher:** Stryker®, 715 mm × 2,100 mm **Mattress:** it was removed for the study **Backboard:** not used The height of the bed and stretcher in relation to the floor was 55 cm (no ladder was used).	There were no significant differences between the chest compression maneuvers carried out on an emergency stretcher (narrow bed) when compared to a standard hospital bed (wide bed), with regard to mean depth (44.27±8.62 mm vs 43.54±10.48 mm, p=0.56) or percentage of compressions with adequate depth (54.85±37.35% vs 61.22±34.71%, p=0.27).
E2 - Chest compressions performed by ED staff: a randomized cross-over simulation study on the floor and on a stretcher. [5] American Journal of Emergency Medicine. Canada. English, 2012. University Hospital.	To analyze the quality of the external chest compressions in simulated cardiac arrest scenarios, comparing the stretcher with the floor.	Randomized prospective simulation study, of the crossover type Human performer (38 nurses and 26 nursing assistants) **Manikin:** Rescusci Anne Laerdal Skill Reporter Modular system **Stretcher:** Promotal armeo hydraulic biplane (107 cm x 190 cm) **Mattress:** 5 cm thickness **Backboard:** it was used, but without description	There was a significant superiority of chest compression quality when carried out on the floor, revealing a 15% reduction in the depth of chest compressions when carried out in the hospital bed.
E3 - Effect of a backboard on compression depth during cardiac arrest in the ED: a simulation study. [17] American Journal of Emergency Medicine. USA. English, 2016. University.	To assess the impact of a board on chest compression depth during cardiac arrest practice sessions.	Randomized, blind study Human performer (43 health professionals) **Manikin:** SimMan Essencial **Stretcher**: Stryker Medical **Mattress:** 10 cm, foam **Backboard:** it was used, but no specifications are described	Using a rigid surface as an adjuvant during cardiopulmonary resuscitation did not improve the mean chest compression depth achieved by the first responders.

Source: Research data

Chart 2. Continued...

Title, journal, country, language, year and researchers' locus	Objectives	Type of study / Thoracic compressions performer / Experiments' manikins and surfaces	Impact of the surfaces on the Chest compressions
E4 - A flexible pressure sensor could correctly measure the depth of chest compression on a mattress. [-18] American Journal of Emergency Medicine. Japan. English, 2016. Private research lab.	To evaluate the depth of chest compressions carried out on a manikin placed on a mattress through a flexible pressure sensor.	Experimental study Automatic compressor. **Manikin:** Little Anne™ manikin (Laerdal, Stavanger, Norway) **Bed:** not used **Stretcher:** not used **Mattress:** urethane foam mattress. Mattress thickness: 8.5 cm. The mattress was placed on the floor. **Backboard:** not used	On the floor, the actual chest compression depth was 5.0±0.0 cm (n=100). On the mattress, the actual chest compression depth measured by the sensor was 4.4±0.0 cm (n=100), showing the impact of the mattress on the quality of chest compression.
E5 - Effects of a backboard, bed height, and operator position on compression depth during simulated resuscitation. [-19] Intensive Care Medicine. United Kingdom. English, 2006. University.	To investigate the effect of a rigid surface, body position in cardiopulmonary resuscitation (CPR), and bed height on chest compression quality during simulated hospital resuscitation.	Randomized, controlled and crossover study Human performer (20 second-year medical students who were Basic Life Support instructors) **Manikin**: resuscitation manikin (Laerdal Medical, Orpington, UK) **Bed:** "standard hospital bed", without specifications **Stretcher:** not used **Mattress**: Height (cm): 17.5; Length (cm): 195; Weight (kg): 12.5. Width (cm): 88. **Backboard:** it was used, but without specifications	In contrast to the current guidelines, the data showed that using a rigid surface did not improve the depth of chest compressions. CPR without a board, 29±7 mm; CPR with a board, 31±10 mm; kneeling on the bed, 30±7 mm; with lowered bed height, 32±10 mm. The participants could not recognize their low quality CPR and there was no difference in the evaluation of fatigue or efficacy of CPR between the surfaces.
E6 - Increasing compression depth during manikin CPR using a simple backboard. [-8] Acta Anaesthesiologica Scandinavica. Denmark. English, 2007. University Hospital.	To compare chest compression depth with and without a backboard.	Randomized, double blind, crossover study Human performer (23 hospital duty members of the CPR team) **Manikin:** Resusci Anne; Laerdal Medical, Stavanger, Norway **Bed:** hospital standard (without specifications) **Stretcher**: not used **Mattress:** Trend Madras Cris CollectionApS, Randers, Denmark, 83 cm x 203 cm x 14 cm, viscoelastic **Backboard:** wood, 44 cm x 58 cm x 1 cm	It was observed that the use of a backboard significantly increased chest compression depth, increasing the mean values from 43 mm to 48 mm using the board.

Source: Research data

Chart 2. Continued...

Title, journal, country, language, year and researchers' locus	Objectives	Type of study Thoracic compressions performer Experiments' manikins and surfaces	Impact of the surfaces on the Chest compressions
		Experimental study	Using the backboard reduced by nearly 50% the impact of mattress deflection on chest compression depth and reduced the rescuer's effort. The backboard doubles the contact area of force transfer, leading to an increased effective rigidity and less mattress compression with the same force applied.
E7 - The impact of compliant surfaces on in-hospital chest compressions: Effects of common mattresses and a backboard.[6] Resuscitation. Norway. English, 2009. Hospital.	To evaluate, in a hospital environment, the influence of different mattresses, with and without a backboard and with or without additional weights (20 kg and 40 kg), on the chest compression movement (sternum-spine).	Human performer (01 rescuer) **Manikin:** Standard System Resusci Anne (Laerdal, Stavanger N) adapted with a linear pot (Type S13FLP100A, Sakae TsushinKogyo Co., Japan) **Bed**: it does not specify the bed model or its characteristics. It informs that the steel platforms for hospital beds have a stiffness of 2,500 N/cm. **Stretcher:** not used **Mattress**: A - Cliniplot III (Hill Rom) 192 cm × 85 cm × 16 cm, plain foam B - Meditherm (Medibol, Valkenswaard) 198 cm × 84 cm× 14 cm. Construction in two layers, with different rigidity: 70 N/cm upper and 105 N/cm lower, and 40% of the total depth of the mattress. C - Atmos Air 9000 (Hill Rom) 202 cm × 82 cm × 18 cm, it includes centrally located air: 145 cm × 70 cm × 12 cm. - EMS folding stretcher thickness ±5 cm. **Backboard:** the lower bed frame, semi-rigid synthetic Trespa™ brand (Trespa Internacional, Weert, NL) was used. Width and height are 80 cm and 30 cm, respectively. It has a stiffness of 200 N/cm.	The results showed that foam mattresses and tube systems act as springs and follow the movement of the hands, while the "slow foam" mattresses incorporate delays, making it challenging to detect depth and strength. The movement of the rescuer's hands was significantly higher (up to 111 mm to 50 mm compression depth, $p<0.0001$) when the sternum-spine compressions were carried out without a backboard than with a board, and this variable also depended on the type of mattress and on the compression force.

Source: Research data

Chart 2. Continued...

Title, journal, country, language, year and researchers' locus	Objectives	Type of study Thoracic compressions performer Experiments' manikins and surfaces	Impact of the surfaces on the Chest compressions
E8 - The use of dual accelerometers improves measurement of chest compression depth. [20] Resuscitation. Korea. English, 2012. University.	To compare the depth of chest compressions using two double accelerometers (a1) and a single accelerometer (A2) on the inflatable air and foam mattress.	Experimental study Human performer (8 rescuers trained in BLS) **Manikin:** Repusci Anne Modular System Skill Reporter **Bed:** not used (the experiment was carried out on the floor) **Bed:** not used **Mattress:** 1 - Hard floor 2 - Stryker foam mattress measuring 66 cm × 192 cm and with a thickness of 7.5, soft foam made with polyurethane coating. 3 - Foam mattress + backboard 4 - Inflated air mattress (23 mmHg pressure, 80 cm × 10 cm × 180 cm, MD-300 TPU2, polyurethane, Eunhye Medical Co., Korea 5 - Air mattress + backboard **Backboard:** 45 cm × 60 cm × 1 cm; Plastic Lifeline, SungShimMed-Co., Korea	When chest compression was carried out with the manikin lying on the floor, there was no significant difference between the measurement techniques ($p>0.05$) but, when the manikin was lying on the foam and the inflated air mattress support system, the use of the feedback system by means of two accelerometers significantly improved the estimate for the depth of chest compressions, regardless of the presence or absence of a backboard ($p<0.001$). It was concluded that, when PCR is carried out with the feedback system using an accelerometer, using a backboard can increase chest compression accuracy on a foam mattress.
E9 - The impact of backboard size and orientation on sternum-to-spine compression depth and compression stiffness in a manikin study of CPR using two mattress types. [9] Resuscitation. South Africa English, 2012. University.	To explore how backboard orientation and size affect chest compressions during cardiopulmonary resuscitation (CPR).	Experimental study Automatic compressor **Manikin:** ALS Trainer Manikin, Laerdal **Bed:** Arjo-Hunt **Stretcher**: N/A **Mattress:** 1 - Mattress 1 (Mat1) was 190 cm x 92 cm x 17 cm and had a density of 0.4038 g/cm^3 2 - Mattress 2 (Mat2) was 198 cm x 86 cm x 17.2 cm with a density of 0.4097 g/cm^3 **Backboard:** the dimensions of both backboards used were as follows: A: 86 cm x 50 cm x 1.2 cm B: 56 cm x 43 cm x 1.1 cm, and had densities of 0.800 and 1.410 g/cm^3, respectively.	It was verified that the effect of backboard size on the performance of chest compressions during CPR was considered significant with the larger board producing deeper chest compressions and greater lumbar support rigidity than the smaller board.

Source: Research data

Chart 2. Continued...

Title, journal, country, language, year and researchers' locus	Objectives	Type of study Thoracic compressions performer Experiments' manikins and surfaces	Impact of the surfaces on the Chest compressions
E10 - Comparison of experimental chest compression data to a theoretical model for the mechanics of constant peak displacement cardiopulmonary resuscitation. -21 Academic Emergency Medicine. South Africa. English, 2011. University.	To validate an existing theoretical model for the constant peak displacement mechanics of cardiopulmonary resuscitation, using experimental data obtained for several different support surfaces and chest compression rates.	Experimental study Automatic compressor **Manikin:** Trainer ALS Manikin, Laerdal **Bed:** Arjo-Hunt **Stretcher**: N/A **Mattress:** 1 - Mattress 1 (Mat1) was 190 cm x 92 cm x 17 cm and had a density of 0.4038 g/cm^3 2 - Mattress 2 (Mat2) was 198 cm x 86 cm x 17.2 cm, with a density of 0.4097 g/cm^3 **Backboard**: the dimensions of both backboards used were as follows: A: 86 cm x 50 cm x 1.2 cm B: 56 cm x 43 cm x 1.1 cm, respectively, with densities of 0.800 and 1.410 g/cm^3	The predictions of the model showed that, when the rigidity of the support surface is less than 250 N/cm, the benefit of using a backboard is higher than in more rigid support surfaces.
E11 - Use of backboard and deflation improve quality of chest compression when cardiopulmonary resuscitation is performed on a typical air inflated mattress configuration. -22 Journal of Korean Medical Science. Korea. English, 2013. University.	The study compared the depth of chest compressions in four settings: A - Bed frame without mattress B - Empty air mattress resting on a foam mattress on the bed frame C - Inflated air mattress resting on a foam mattress on the bed frame D - Same as C inserting a backboard between the manikin and the inflated mattress	Randomized experimental study Human performer (08 CPR providers) **Manikin:** Resusci Anne Modular System Skill Reporter **Bed:** not used **Stretcher:** Striker **Mattress:** 1 - Foam mattress measuring 192 cm x 66 cm x 8 cm 2 - Inflatable mattress measuring 80 cm x 180 cm x 10 cm **Backboard**: 45 cm x 60 cm x 1 cm	Deflation of the air mattress significantly reduced mattress deflection (B: 14.74±1.36 vs C: 30.16±3.96, p<0.001). Using a backboard also reduced mattress deflection (C: 30.16±3.96 vs D: 25.46±2.89, p=0.002). However, the air mattress deflection reduced mattress deflection more than using a backboard (B: 14.74±1.36 vs D: 25.46±2.89, p=0.002). Using a deflated air mattress and the backboard simultaneously reduces mattress deflection; thus, it helps to obtain the necessary chest compression depth during CPR.

Source: Research data

Chart 2. Continued...

Title, journal, country, language, year and researchers' locus	Objectives	Type of study / Thoracic compressions performer / Experiments' manikins and surfaces	Impact of the surfaces on the Chest compressions
E12 - Does the bed frame deflection occur along with mattress deflection during in-hospital cardiopulmonary resuscitation? An experiment using mechanical devices.[23] Hong Kong Journal of Emergency Medicine. Korea. English, 2016. University.	A study evaluating deflection of the bed frame during chest compressions. A "firm bed" model (ER-ST) referred to as floor-like bed was designed to compare deflection of the structure of another 2 beds X a Firm Bed.	Experimental study	The deflections of the Stryker and ER-SC mattresses were measured at 11.2 mm and 0.67 mm, respectively. The deflection of the bed frame for STS and ER-SC was 0.95 mm and 5.17 mm, respectively. The study confirmed that deflection of the bed frame occurs while performing chest compressions on a manikin placed on a bed and can reduce chest compression depth during CPR, increasing the rescuer's workload.
		Human performer (01 rescuer trained in Basic Life Support)	The deflection of the soft mattress was higher than that of the hard mattress and, by using a board, deflection was reduced, but not completely removed.
		Manikin: Resusci Anne QCPR **Bed:** a "floor-like bed" model was designed = made with plywood board coupled to a bed measuring 50 cm wide x 60 cm long x 70 cm in height **Stretcher:** Stryker Stretcher (STS) and SK-180 emergency room stretcher cart (RE-ST; Hanlim Medical Equipment) **Mattress:** mattresses from the manufacturers was used, the first with 9 cm and the second with 5 cm **Backboard**: 55 cm wide x 42 long x 1.5 cm in height	

Source: Research data

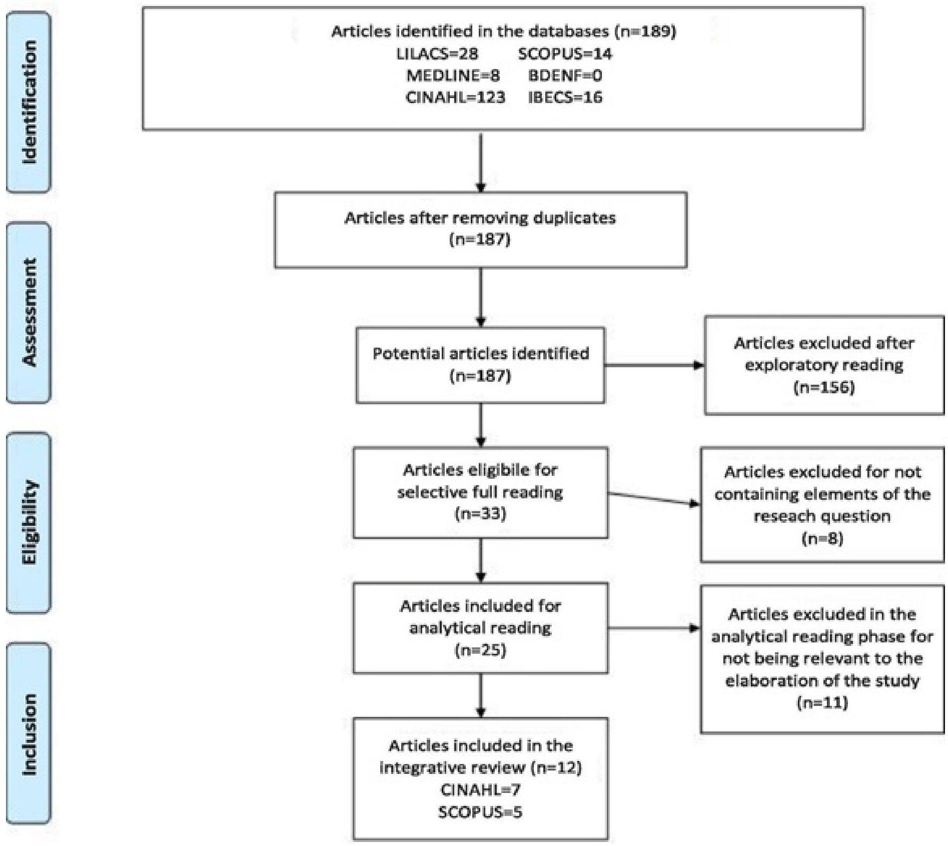

Figure 1. Flowchart identifying the selection process of the studies selected to comprise the integrative review. Rio de Janeiro, RJ, Brazil, 2020.
Source: Research data.

surface, only E1 described its dimensions. No study described the material or other composition characteristics of the beds. As for the backboards, six different sizes were described. Concerning the material, although most of the studies have not provided information (55.5%), the materials indicated were plastics (22.2%), followed by wood (11.1%) and semi-synthetic materials (11.1%). The synthesis of the compression surfaces' characteristics is shown in Table 1.

Regarding the impact of the surfaces on the quality of chest compressions, the studies discuss influences of the type of compression surface on the force required to perform them, such force being significantly associated to the set of bed/stretcher and mattress used. Studies E2, E4, E8 and E12 considered the floor as the gold standard for high-quality chest compression depth. E2 and E4 addressed the impact of the stretcher/bed/mattress with the reduction in the quality of the compressions compared to the floor. Studies E3, E5, E6, E7, E10, E11 and E12 investigate the impact of backboards on the quality of chest compression, presenting differences in the results, sometimes showing benefits of using the board in the depth of compressions, and others demonstrating that its use does not lead to improvements in the quality of the maneuvers, and that they may even delay the start of the compressions. In relation to backboard orientation and size, it is noted that larger and longer boards produce greater lumbar support and improve the quality of chest compressions (E9).

Other characteristics of the surfaces that can influence the quality of compressions are larger mattresses and mattresses with high-technology materials for pressure reduction (E7) and wider beds (E1), which present negative impacts on the quality of chest compressions. Another characteristic that was shown to generate an impact on the quality of chest compressions is deflection of the beds and mattresses, directly related to these surfaces' characteristics (E8, E11, E12).

DISCUSSION

The results found about the characteristics and impact of the surfaces where the patient is supported (bed/stretcher, mattress and backboard) on chest compression indicate the following: the material, structure, dimensions, arrangement and knowledge on the mechanics of the mattress and backboard effects can reduce the quality of chest compressions, especially depth; lack of a uniform standard for structuring the surfaces regarding dimensions and equipment; and divergence on the indication to use backboards.

Chest compression is related to the maintenance of cardiac output and, consequently, to cerebral blood flow during CPR. CC is

Table 1. Characterization of the mattresses and backboards regarding dimensions and materials. Rio de Janeiro, RJ, Brazil, 2020.

Surface/ Characteristics	Dimensions of the characteristics					
Mattress	n	%	Mean	SD*	Min	Max
Dimensions						
Width (cm)			81.1	8.2	66	92
Length (cm)			192.9	7.6	180	203
Thickness (cm)			11.3	4.7	5	18
Material used						
Foam	5	38.4	-	-	-	-
Viscoelastic	1	7.7	-	-	-	-
Inflatable	2	15.4	-	-	-	-
No information	5	38.4	-	-	-	-
Backboard	n	%	Mean	SD*	Min	Max
Dimensions						
Width (cm)			43.9	7.9	30	55
Length (cm)			63.1	15	42	86
Thickness (cm)			1.1	0.2	1	1.5
Material used						
Plastic	2	22.2	-	-	-	-
Wood	1	11.1	-	-	-	-
Semi-synthetic	1	11.1	-	-	-	-
No information	5	55.5	-	-	-	-

SD = Standard Deviation.
Source: Research data

considered the most crucial care skill because it maintains cerebral perfusion during the CPR maneuvers. Similar to the compression frequency, some studies show that a proper compression depth range is also required. Several studies suggested that achieving a compression depth of nearly 5 cm is associated with better results when compared to more superficial compressions[24-25]. According to clinical and animal studies that evaluated the quality of the CPR effect on the clinical outcome, a change from 10% to 20% (0.5-1 cm) in chest compression depth can have a clinical impact, as described in cardiac output, blood flow or successful defibrillation associated with CPR[26].

CPA events in extra-hospital environments take place mainly on the floor, thus having a variable that directly favors reaching the desired depth for the chest compressions. The floor is considered the gold standard, as it is a hard surface that enables sinking the chest at the desired depth during CPR[18,20,23]. It is emphasized that chest compressions carried out on the floor present significantly increased quality about depth compared to a hospital bed, with a 15% reduction in the depth of the compressions carried out on such surfaces[5]. However, in the context of health care at the in-hospital environment, where the patients are usually in beds/stretchers, performing chest compressions on the floor and being unusual can be impractical. Considering that procedures such as airway management, insertion of intravenous or intraosseous access, use of devices for monitoring and administration of drugs may be needed during in-hospital CPR, moving the patient from a bed/stretcher to the floor to perform high-quality chest compressions may not be effective and can be associated with high risks. The benefits of moving a patient from a bed/stretcher to the floor to perform CPR were not evaluated[26].

To improve the quality of chest compressions, especially in situations where a patient suffers cardiac arrest in the bed, the guidelines dealing with resuscitation recommend that a backboard is to be inserted under the patient[1]. However, the AHA recognizes a weak basis for this recommendation, stating insufficient evidence for or against using backboards during CPR[27]. Theoretically, using a backboard would promote stability and reduce chest and mattress complacency allowing the rescuer to produce deeper chest compressions.

When the patient's chest is compressed on a firm surface, the sternum's distance is pressed toward the vertebrae directly related to the compression force applied. On a mattress, the sternum-vertebral displacement is influenced by a combination of compression force and the compression degree of the underlying surface (bed/stretcher + mattress). Mathematical data suggest that placing a backboard between the patient and the mattress improves chest compression depth, increasing mattress rigidity[28].

Many studies have been conducted to investigate the influence of the lumbar support provided by inserting a backboard while performing CPR[6,8,19,22,29-32]. Some studies suggest that chest compressions can be degraded by non-rigid support surfaces or enhanced, such as increased depth, duration, and frequency, when a board is used[6,9,20,23,29,33-34]. In contrast, other papers indicate that the presence of a backboard does not significantly improve the quality of the chest compressions during CPR[17,19,35].

Another point discussed about using backboards is related to the time needed to place the device on the patient's chest. Time is a critical factor in CPR, and it was shown that interruptions in chest compressions reduce the rate of successful defibrillation. It was shown that a delay of only 15 seconds compromises the rate of successful resuscitation during advanced cardiac life support and increases the adverse results if return of spontaneous circulation is achieved[36]. Actions such as placing a backboard can cause delays in starting the chest compressions or interruptions after their initiation[27,36], with adverse consequences for the success of resuscitation, and can only be accepted if the action is helpful to improve the performance of chest compression.

Carrying out good chest compressions is highly challenging and can even be more complex when we are in a scenario with a soft surface such as a mattress. Depth decreases when pressure is applied on a mattress and even using a hard surface may not be sufficient to ensure the depth indicated by the international guidelines for PCR[17]. The research results suggest that the type of bed and mattress used is a relevant factor for the force needed to attain chest compression quality, such force being significantly associated to the set of bed/stretcher + mattress used[5-6,8-9,16,19,21].

Concerning the characteristics of the mattresses, it is observed that those composed of high-technology materials negatively impact on the quality of chest compressions. Challenged to prevent pressure ulcers, the hospitals introduced different support systems for pressure relief, especially for bedridden patients, starting with simple foam mattresses. The so-called "slow foam" mattresses or "hybrid of low-pressure foam" mattresses, are increasingly used as base mattresses[37]. These systems incorporate several layers of materials with different viscoelastic properties for weight to be equally distributed; this technology replaced the air-filled systems. Several studies showed that, when compared to the floor, support surfaces such as foam mattresses and mattresses that redistribute pressure (inflated and deflated) and mobile stretchers for ambulances, reduce chest compression depth in a resuscitation manikin[30-31,38].

Another aspect that can affect the quality of the chest compressions carried out in hospital beds is that the beds/stretchers can oscillate when the rescuer performs chest compressions. Such oscillation can occur through deflection of the mattress or of the bed/stretcher frame itself, reducing the quality of chest compression[23,29,39]. Studies indicate that mattress deflection can be reduced, but that it cannot be removed entirely using a backboard[6,8-10,29-30,40].

The impact of mattress and bed/stretcher frame deflection can be explained by a law of physics called Hooke's Law[41]. When compressing the chest, this behaves like a spring, that is, the force needed to deform it is proportional to the effective displacement. Therefore, by performing compression on the floor, which has a higher elastic constant, any force applied will be preferentially used to deform the chest. However, when the patient lies on a medium with a lower elastic constant such as mattresses, while applying a force, this will first deform the medium which presents lower resistance. Only when the force required to deform the mattress is more significant than that for deforming the chest will it start to be compressed.

Study limitations

Although all the studies that comprised this review were in-laboratory experimental studies, there are limitations for the number of papers that met the research question due to the lack of clinical studies and to the absence of a detailed description of the compression surfaces used in these studies, which limited a larger scope of the results in understanding the phenomenon under study. It is also pointed out that no guidelines or recommendations that would point to the best characteristics for the compression surfaces were identified.

Contributions to health and nursing

The study contributes to warning about the importance that the health staff is attentive to the issue of the compression surfaces on which the patient is positioned during CPR and their potential impact on high-quality chest compressions, especially in environments with critically ill patients, as these have a higher chance of evolving to CPA, which requires fast and safe assistance.

The managers need to be aware of the type and characteristics of these surfaces during the incorporation of technology in the hospital setting and the professionals who directly serve the patient when deciding on the best support surface given, optimizing the clinical outcomes. As there is yet no formal indication of the ideal surface for performing chest compressions, new clinical studies (especially in the national scope) are recommended that test the effect of the compression surfaces on the quality of CPR.

CONCLUSION

This review identified that the characteristics of the surfaces on which the patient is supported (bed/stretcher mattress and backboard) impact the quality of chest compressions, especially in their depth. These characteristics involve the material, structure, size, disposition and knowledge on the mechanics of the mattress and backboard effects.

Based on the results presented, it is observed that the bed dimensions, and mainly those of the mattress, are correlated with the quality of chest compressions, especially with their depth. Thus, large mattresses and mattresses with high-technology materials for pressure reduction and large beds exert negative impacts on the quality of chest compressions.

Another characteristic that showed to exert an impact on the quality of chest compressions is the deflection of beds and mattresses, directly related to these surfaces' characteristics. It was observed that the use of backboards could only reduce deflection. Consequently, there is a need to know more information about the damping/deflection effect of the surfaces used during cardiopulmonary resuscitation and think about strategies and technologies to reduce or eliminate this effect.

When it comes to using backboards and their impact on high-quality chest compressions, the studies analyzed present different information and, therefore, point to more robust research studies on the theme. This review suggests that new experimental studies should be conducted to understand better the impact of the surfaces where the patient is supported on the quality of chest compressions.

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