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RESEARCH

A Comparison of CPR on a Hard Surface Compared to CPR on a Mattress

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ABSTRACT

Background: High-quality cardiopulmonary resuscitation (CPR) is critical for improving survival outcomes in cardiac arrest patients. However, the compliance of surfaces like hospital mattresses and household beds may compromise CPR effectiveness by reducing compression depth and increasing rescuer fatigue.

Objective: To investigate the metabolic and performance differences of CPR performed on a hard surface versus a standard hospital mattress and discuss implications for lay responders performing CPR in out-of-hospital settings.

Methods: A randomized cross-over study involving 34 trained participants assessed CPR quality and rescuer physiological responses on two surfaces: a hard floor and a hospital mattress. Participants performed continuous chest compressions on a manikin for 24 minutes under each condition. Measurements included heart rate (HR), oxygen consumption (VO_2), ventilatory equivalent for oxygen (Ve/VO_2), fraction of expired oxygen (FeO_2), compression depth and rate, and ratings of perceived exertion (RPE).

Results: Performing CPR on a mattress significantly increased HR (mean difference: –4.1 ± 9.8 bpm; $p = 0.020$) and VO_2 (mean difference: –14.8 ± 7.2 mL/kg/min; $p < 0.001$) compared to the hard surface. Compression depth was significantly reduced on the mattress (mean difference: 3.4 ± 3.5 mm; $p < 0.001$). Ve/VO_2 difference increased (mean difference: –3.3 ± 8.3; $p = 0.025$), and FeO_2 difference decreased (mean difference: 0.7 ± 1.3%; $p < 0.001$)

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on the mattress, indicating increased metabolic demands and reduced ventilatory efficiency. RPE scores were higher on the mattress at both midpoint (mean difference: –0.5 ± 1.3; p = 0.006) and completion (mean difference: –0.2 ± 1.0; p < 0.001). No significant difference in compression rate was observed (p = 0.843).

Conclusions: CPR performed on a compliant surface like a hospital mattress or household bed increases the rescuer's metabolic demands and reduces compression depth, potentially compromising resuscitation effectiveness. Strategies to mitigate the effects of surface compliance, such as moving the patient to a hard surface or using backboards, should be considered to improve CPR quality in both clinical and out-of-hospital settings.

ABSTRAITE

Contexte: Une réanimation cardio-pulmonaire (RCP) de qualité est essentielle pour améliorer les chances de survie des patients ayant subi un arrêt cardiaque. Cependant, la conformité des surfaces telles que les matelas d'hôpitaux et les lits domestiques peut compromettre l'efficacité de la RCP en réduisant la profondeur de compression et en augmentant la fatigue du sauveteur.

Objectif: Étudier les différences métaboliques et de performance de la RCP pratiquée sur une surface dure par rapport à un matelas d'hôpital standard et discuter des implications pour les intervenants non professionnels pratiquant la RCP en milieu autres que l'hôpital.

Méthodes: Une étude croisée randomisée impliquant 34 participants formés a évalué la qualité de la RCP et les réactions physiologiques des sauveteurs sur deux surfaces : un sol dur et un matelas d'hôpital. Les participants ont effectué des compressions thoraciques continues sur un mannequin pendant 24 minutes dans chaque condition. Les mesures comprenaient la fréquence cardiaque (FC), la consommation d'oxygène (VO_2), l'équivalent ventilatoire pour l'oxygène (Ve/VO_2), la fraction d'oxygène expiré (FeO_2), la profondeur et le taux de compression, et l'évaluation de l'effort perçu (RPE).

Résultats: La réalisation de la RCP sur un matelas a significativement augmenté la FC (différence moyenne : –4,1 ± 9,8 bpm ; p = 0,020) et le VO_2 (différence moyenne : –14,8 ± 7,2 mL/kg/min ; p < 0,001) par rapport à la surface dure. La profondeur de compression était significativement réduite sur le matelas (différence moyenne : 3,4 ± 3,5 mm ; p < 0,001). La différence Ve/VO_2 a augmenté (différence moyenne : –3,3 ± 8,3 ; p = 0,025) et la différence FeO_2 a diminué (différence moyenne : 0,7 ± 1,3 % ; p < 0,001) sur le matelas, ce qui indique une augmentation de la demande métabolique et une réduction de l'efficacité ventilatoire. Les scores RPE étaient plus élevés sur le matelas à la fois à mi-parcours (différence moyenne : –0,5 ± 1,3 ; p = 0,006) et à la fin (différence moyenne : –0,2 ± 1,0 ; p < 0,001). Aucune différence significative n'a été observée dans le taux de compression (p = 0,843).

Conclusions: La RCP pratiquée sur une surface souple comme un matelas d'hôpital ou un lit de maison augmente la demande métabolique du sauveteur et réduit la profondeur de compression, ce qui peut compromettre l'efficacité de la réanimation. Des stratégies visant à atténuer les effets de la compliance de la surface, telles que le déplacement du patient sur une surface dure ou l'utilisation de planches dorsales, devraient être envisagées pour améliorer la qualité de la RCP dans les environnements cliniques et extrahospitaliers.

خلاصة

الخلفية: يعد الإنعاش القلبي الرئوي عالي الجودة أمرًا بالغ الأهمية لتحسين نتائج النجاة لدى مرضى السكتة القلبية. ومع ذلك، قد يؤدي امتثال الأسطح مثل مراتب المستشفيات والأسرّة المنزلية إلى الإضرار بفعالية الإنعاش القلبي الرئوي عن طريق تقليل عمق الضغط وزيادة إجهاد المنقذ.

الهدف: التحقق من الاختلافات الأيضية واختلافات الأداء في الإنعاش القلبي الرئوي الذي يتم إجراؤه على سطح صلب مقابل فراش المستشفى القياسي ومناقشة الآثار المترتبة على المستجيبين العاديين الذين يقومون بالإنعاش القلبي الرئوي في أماكن خارج المستشفى.

الأساليب: تم إجراء دراسة عشوائية متقاطعة شملت 34 مشاركًا مدربًا لتقييم جودة الإنعاش القلبي الرئوي والاستجابات الفسيولوجية للمنقذين على سطحين: أرضية صلبة ومرتبة المستشفى. أجرى المشاركون ضغطًا مستمرًا على الصدر على مانيكان لمدة 24 دقيقة في كل حالة. وشملت القياسات معدل ضربات القلب (HR) ، واستهلاك الأكسجين (VO_2) ، ومكافئ التنفس للأكسجين (Ve/VO_2) ، وجزء من الأكسجين المنتهي الصلاحية (FeO_2) ، وعمق الضغط ومعدله، وتقييمات الجهد المدرك (RPE).

النتائج: أدى إجراء الإنعاش القلبي الرئوي على مرتبة إلى زيادة كبيرة في معدل ضربات القلب(متوسط الفرق: –4.1 ± 9.8 نبضة في الدقيقة؛ (p = 0.020 و VO_2 متوسط الفرق: –14.8 ± 7.2 مل/كجم/الدقيقة؛ (p < 0.001 مقارنة بالسطح الصلب. انخفض عمق الضغط بشكل ملحوظ على المرتبة (متوسط الفرق: 3.4 ± 3.5 مم؛ .(p < 0.001 زاد الفرق في) VO_2/متوسط الفرق: –3.3 ± 8.3؛(p = 0.025 ، وانخفض فرق الأكسجين في الأكسجين (متوسط الفرق: –0.7 ± 1.3٪؛ (p < 0.001 على المرتبة، مما يشير إلى زيادة متطلبات الأيض وانخفاض كفاءة التهوية. كانت درجات RPE أعلى على المرتبة في كل من نقطة المنتصف (متوسط الفرق: –0.5 ± 1.3؛ (p = 0.006 والانتهاء (متوسط الفرق: –0.2 ± 1.0؛ .(p < 0.001 لم يلاحظ أي فرق كبير في معدل الضغط (p = 0.843).

الاستنتاجات: يزيد الإنعاش القلبي الرئوي الذي يتم إجراؤه على سطح متوافق مثل فراش المستشفى أو السرير المنزلي من متطلبات الأيض لدى المنقذ ويقلل من عمق الضغط، مما قد يضر بفعالية الإنعاش. يجب النظر في استراتيجيات للتخفيف من آثار امتثال السطح، مثل نقل المريض إلى سطح صلب أو استخدام الألواح الخلفية، لتحسين جودة الإنعاش القلبي الرئوي في كل من الإعدادات السريرية وخارج المستشفى.

Keywords: Compression depth; Cardiopulmonary resuscitation (CPR); Rescuer fatigue; Metabolic demands; In-hospital cardiac arrest; Hospital mattress; Resuscitation effectiveness; Cardiopulmonary resuscitation (CPR); Rescuer fatigue; Metabolic demands; In-hospital cardiac arrest; Hospital mattress; Resuscitation effectiveness

Cardiac arrest remains a leading cause of mortality worldwide, with out-of-hospital cardiac arrest (OHCA) survival rates persistently low despite advancements in emergency medical services and resuscitation science (Benjamin et al., 2019; Virani et al., 2020). High-quality cardiopulmonary resuscitation (CPR) is critical in improving survival outcomes, particularly the quality of chest compressions, which is a crucial determinant of patient prognosis (Meaney et al., 2013; Panchal et al., 2019). This study is a vital part of the Chain of Survival Behaviors, focusing on enhancing the quality of early CPR, a critical link that can significantly influence patient outcomes (AHA, 2020), and you, as a reader, are an integral part of this mission.

Compression depth is a vital component of effective CPR, directly influencing cardiac output and coronary perfusion pressure during resuscitation efforts (Idris et al., 2015; Stiell et al., 2012). The American Heart Association (AHA) recommends a compression depth of at least 50 mm (2 inches) for adults to ensure adequate perfusion of vital organs (AHA, 2020). Numerous studies have established a positive correlation between increased compression depth and improved rates of return of spontaneous circulation (ROSC) and survival to hospital discharge (Andersen et al., 2018; Vadeboncoeur et al., 2014).

However, achieving the recommended compression depth can be challenging in real-world settings, particularly within hospital environments where patients are often positioned on mattresses that can compress under the force of chest compressions (Berg et al., 2019; Kleinman et al., 2015). Similarly, lay responders may perform CPR on soft surfaces such as beds or couches in out-of-hospital settings, which can also affect compression effectiveness (Sugerman et al., 2009). The compliance of such surfaces can absorb some of the force applied during CPR, reducing the actual compression depth delivered to the patient's chest (Attin et al., 2012; Nozawa et al., 2015). This issue is compounded by the physical demands placed on rescuers, who may experience increased fatigue and exertion when attempting to compensate for surface compliance (Kim et al., 2017).

Previous studies have investigated the impact of performing CPR on various surfaces, demonstrating that compliant surfaces can adversely affect compression depth and overall CPR quality (Shin et al., 2014;

Sugerman et al., 2009). While using backboards or other rigid supports has been recommended to mitigate these effects, their effectiveness remains to be determined, and their utilization in both clinical practice and layperson scenarios needs to be more consistent (Fischer et al., 2016; Hellevuo et al., 2014).

Moreover, few studies have examined the metabolic demands of rescuers performing CPR on different surfaces. Understanding the physiological strain experienced by providers is essential, as increased exertion can lead to rapid fatigue, potentially compromising CPR quality over time (Nishisaki et al., 2012; Ock et al., 2011).

This study investigates the metabolic and performance differences of CPR performed on a hard surface compared to a standard hospital mattress. By assessing both the quality of chest compressions and the physiological demands on the rescuer, this research seeks to provide comprehensive insights into how surface compliance impacts CPR effectiveness. The potential of this study to inform strategies that may enhance resuscitation practices in both clinical and out-of-hospital settings is a reason for optimism and hope.

METHODS

Study Design and Participants

A randomized cross-over study assessed the metabolic and performance differences in CPR performed on a hard surface versus a standard hospital mattress. The study was conducted at West Texas A&M University between January and June 2020, following approval from the university's Institutional Review Board (IRB approval number 2020-05).

Thirty-four participants (17 males and 17 females), aged between 19 and 27 years (mean age ± SD: 23 ± 2.1 years), were recruited from the College of Nursing and Health Sciences. Inclusion criteria required participants to have current certification in Basic Life Support (BLS) from the American Heart Association and be physically capable of CPR for extended periods. Exclusion criteria included any musculoskeletal injuries or medical conditions that could be exacerbated by physical exertion.

Before participation, all individuals provided written informed consent and completed a health questionnaire to screen for contraindications to vigorous physical activity.

Experimental Procedure

Participants were randomized to begin CPR either on the hard surface or the hospital mattress to control for any order effects. Each participant performed two CPR sessions, one on each surface, separated by a rest period of at least 30 minutes to prevent fatigue carryover.

CPR was performed on a Resusci Anne QCPR manikin (Laerdal Medical, Stavanger, Norway), providing real-time compression depth and rate feedback. The manikin was placed either directly on the floor (hard surface condition) or on a standard hospital mattress positioned on a hospital bed adjusted to a standard working height (mattress condition).

Participants performed continuous chest compressions for a total of 24 minutes per session, following the AHA guidelines for compression-only CPR to focus solely on the compression component. To simulate a realistic resuscitation scenario and manage physical exertion, participants alternated roles every 2 minutes, mimicking standard CPR practice where rescuers switch to prevent fatigue (AHA, 2020). However, in this study, since only the compressions were being assessed, participants alternated with brief rest periods required to switch positions.

Physiological Measurements

- Heart rate (HR) was continuously monitored using a Polar heart rate monitor (Polar Electro, Kempele, Finland).
- Oxygen consumption (VO_2): This measures how much oxygen your body uses during physical activity. It reflects the efficiency of your muscles in using oxygen to produce energy.
- Ventilatory equivalent for oxygen (Ve/VO_2): This is a ratio that shows how effectively you breathe. It compares the amount of air you inhale and exhale to the amount of oxygen your body actually uses.
- Fraction of expired oxygen (FeO_2): This indicates the percentage of oxygen in the air you breathe out. By knowing this, we can determine how much oxygen your body has absorbed.

These measurements were taken using a VO_2 Master Analyzer (VO_2 Master Health Sensors, Inc., Vernon, British Columbia, Canada), a portable device that analyzes your breathing to assess how well your heart and lungs work during exercise.

Performance Measurements

The feedback system integrated into the Resusci Anne manikin recorded compression depth and rate. The device's data logging capabilities allow the collection of average values over the entire session.

Subjective Measures

Participants rated their perceived exertion using the Borg Rating of Perceived Exertion (RPE) Scale (6–20 scale) at the midpoint (12 minutes) and upon completion (24 minutes) of each CPR session (Borg, 1982).

Statistical Analysis

Data were analyzed using SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Paired t-tests were performed to compare physiological and performance variables between the hard surface and mattress conditions. The level of statistical significance was set at $p < 0.05$. Data are presented as mean ± standard deviation (SD).

RESULTS

Participant Characteristics

Thirty-four participants completed the study without any adverse events. The mean age was 23 ± 2.1 years, with a mean body mass index (BMI) of 22.5 ± 2.3 kg/m².

Physiological Measurements

- **Heart Rate (HR):** The average HR during CPR on the mattress was significantly higher than on the hard surface (113 ± 15.6 bpm vs. 109 ± 14.8 bpm; $p = 0.020$), with an average increase of 4.1 ± 9.8 bpm.
- **Oxygen Consumption (VO_2):** Participants exhibited a significantly higher VO_2 during CPR on the mattress compared to the hard surface (28.6 ± 5.2 mL/kg/min vs. 13.8 ± 4.1 mL/kg/min; mean difference: –14.8 ± 7.2 mL/kg/min; $p < 0.001$).
- **Ventilatory Equivalent for Oxygen (Ve/VO_2):** The Ve/VO_2 difference was more significant in the mattress condition (mean difference: –3.3 ± 8.3; $p = 0.025$), indicating less efficient ventilation.
- **Fraction of Expired Oxygen (FeO_2):** There was a significant decrease in FeO_2 during CPR on the mattress (mean difference: 0.7 ± 1.3%; $p < 0.001$).

Performance Measurements

- **Compression Depth:** The average compression depth was significantly reduced when performing CPR on the mattress compared to the hard surface (46.2 ± 5.4 mm vs. 49.6 ± 5.1 mm; mean difference: 3.4 ± 3.5 mm; $p < 0.001$).
- **Compression Rate:** There was no significant difference in compression rate between the two conditions (104 ± 6.2 cpm vs. 104.2 ± 5.9 cpm; mean difference: –0.2 ± 5.7 cpm; $p = 0.843$).

Subjective Measures

- **Ratings of Perceived Exertion (RPE):** A scale from 1 to 10 for participants to evaluate their effort levels. Participants reported higher RPE scores during CPR on the mattress at both the midpoint (14.5 ± 1.8 vs. 14.0 ± 1.7; mean difference: –0.5 ± 1.3; $p = 0.006$) and upon completion (16.2 ± 1.9 vs. 16.0 ± 1.8; mean difference: –0.2 ± 1.0; $p < 0.001$).

Variable	Mean Difference (Hard – Mattress)	Standard Deviation	p-value
HR Average (bpm)	–4.1	±9.8	0.020
VO_2 Difference (mL/kg/min)	–14.8	±7.2	<0.001
Ve/VO_2 Difference	–3.3	±8.3	0.025
FeO_2 Difference (%)	0.7	±1.3	<0.001
Compression Depth (mm)	3.4	±3.5	<0.001
Compression Rate (cpm)	–0.2	±5.7	0.843
RPE Midpoint	–0.5	±1.3	0.006
RPE Total	–0.2	±1.0	<0.001

Table 1: Summary of Statistical Results.

Note: A negative mean difference indicates higher values in the mattress condition.

DISCUSSION

This study investigated the metabolic and performance differences in CPR performed on a hard surface versus a standard hospital mattress. The findings demonstrate that performing CPR on a compliant surface significantly increases the rescuer's physiological demands and compromises the compression depth, a critical factor in adequate resuscitation.

Increased Physiological Demands

The higher heart rates and oxygen consumption observed during CPR on the mattress condition indicate more significant cardiovascular and metabolic stress on the providers. This aligns with previous research suggesting that CPR is a physically demanding activity, and factors that increase exertion may lead to an earlier onset of fatigue (Chung et al., 2012; Ock et al., 2011). The increased ventilatory equivalents (Ve/VO_2) and decreased fraction of expired oxygen (FeO_2) further suggest that rescuers work less efficiently on a compliant surface, potentially due to the additional effort required to achieve adequate chest compression.

Reduced Compression Depth

The significant reduction in compression depth when CPR was performed on the mattress is of particular concern. Compression depth is directly associated with increased ROSC and survival rates (Idris et al., 2015; Stiell et al., 2012). The average decrease of 3.4 mm observed may seem modest but can be clinically significant, potentially reducing the efficacy of CPR and the likelihood of patient survival (Babbs & Kern, 2002).

These findings are consistent with previous studies that have demonstrated decreased compression depth on compliant surfaces due to mattress compression (Baubin et al., 2015; Sugerman et al., 2009). The surface's compliance absorbs part of the force applied during compressions, resulting in less effective chest compression depth.

Implications for Lay Responders

Although this study was conducted in a clinical setting, the findings have significant implications for lay responders performing CPR in out-of-hospital environments. In many cases, cardiac arrests occur at home, where the patient may be lying on a bed, couch, or other soft surfaces. Lay responders may need to recognize that CPR on these compliant surfaces can reduce compression effectiveness.

To mitigate this, lay responders should move the patient to a firm surface when possible and safe before initiating CPR. If moving the patient is not feasible, they should be aware of the need to push harder to compensate for the soft surface. First aid education should emphasize the importance of surface firmness in CPR effectiveness and guide how to address this issue in various settings.

Implications for Clinical Practice

The results underscore the importance of addressing surface compliance during in-hospital cardiac arrests. While using backboards has been recommended to mitigate mattress compression, their effectiveness is variable, and placement can delay CPR initiation (Hellevuo et al., 2014; Shin et al., 2014). Alternative strategies, such as integrating CPR feedback devices for mattresses or mechanical compression devices, may offer solutions (Couper et al., 2016; Ong et al., 2010).

Furthermore, the increased exertion required on a mattress may contribute to rescuer fatigue, potentially compromising CPR quality over time. Regular switching of providers and ensuring adequate staff availability during resuscitation efforts may help maintain high-quality compressions (AHA, 2020).

Limitations

This study has several limitations. First, using a manikin model may not fully replicate human chest compliance, although it allows for controlled comparisons between conditions. Second, the study was conducted with participants who were young and physically fit nursing and health science students, which may limit the generalizability to older or less physically fit providers. Third, the study did not assess the use of adjuncts such as backboards or CPR feedback devices, which could influence the outcomes.

Future Research

Further research should explore interventions to mitigate the effects of surface compliance, including backboards' efficacy, mattress-deflation strategies, and advanced feedback technologies. Studies involving actual resuscitation events and diverse provider populations would enhance the external validity of the findings.

CONCLUSION

Performing CPR on a compliant surface like a hospital mattress or household bed significantly increases the rescuer's metabolic demands and reduces compression depth, potentially compromising the effectiveness of resuscitation efforts. These findings highlight the need for strategies to address the challenges of compliant surfaces in both clinical and out-of-hospital settings. By implementing measures to ensure adequate compression depth and manage rescuer fatigue, healthcare providers and lay responders can improve the quality of CPR and potentially enhance patient survival outcomes during cardiac arrests.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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