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RESEARCH ARTICLE

BIOMECHANICAL COMPARISSON BETWEEN IN-LINE EXTRICATION TECHNIQUES *VERSUS* KENDRICK EXTRICATION DEVICE (KED) IN TRAFFIC ACCIDENTS

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ABSTRACT

Introduction: Worldwide, more than 1.35 million lives are lost annually to road traffic accidents. Care is provided on scene to prevent the occurrence of secondary neurological injuries, forming the cornerstone of emergency medical service (EMS) interventions. Controlled extrication for stable patients is common with attempts to limit the range of spinal column movement using techniques such as self-extrication, in line extrication and/or by utilising short extrication jackets (KED or similar). Recently, bio mechanical studies have challenged the use of indoctrinated EMS techniques. This study intends to add to the body of evidence comparing controlled inline extrication technique, zero angle (AZ) versus the short extrication jacket (KED).***Method***: This is a randomised comparative cohort study analysing the biomechanics of spinal movement during 2 extrication techniques. The study compares a cohort of 74 healthy volunteers of varying sex, height and weight. Volunteers were removed from the simulated vehicle twice using both AZ and KED techniques. Height and weight demographics matched general population attribution. Extrications were undertaken by 12 teams of 3 EMS professionals with more than 5 years experience.Cervical spine motion was measured using a human motion tracker through wireless kinemetry sensors, six infra-red cameras for 3D motion analysis (Spica) and reflective anatomical markers. Wireless inertia sensors were also used to measure the acceleration (accelerometers) and angular velocity (gyroscopes) of the spine during different phases. Primary analysis end points were: head movement, extraction time and patient comfort. ***Results***: The extrication time was significantly shorter with the AZ technique. Head movement was greater when using the KED.The perceived comfort during extrication showed greater comfort in the AZ technique. ***Conclusion***: Extrication technique will vary based on each victim and must be derived upon injury severity. The habitual use of the KED rescue technique needs review especially for taller and obese patients.

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INTRODUCTION

Traffic claims a term adopted according to the Brazilian National Standards Organization (NBR 10697/2020) replaces the wording traffic accidents (1) and remains the main cause of major trauma and death for victims of all ages (2). Globally, traffic claims consistently rank among the most common causes of major injury and death across all age groups, accounting for more than 1.35 million deaths every year worldwide (1). There are many rescue models engaged in trying to reduce this number however, all depend on a pre hospital medical service working in tandem with a fire and rescue service.

While protocols may differ from country to country the extrication of the patient in a safe and timely manner is paramount (3,4). Post collision up to 40% of victims can be trapped within the vehicle and have a higher risk of death than those who are not. Extrication methods are focused on preventing secondary spinal cord injuries by minimising and mitigating spinal column movement. These procedures can be time consuming and must be balanced and titrated against the patients overall clinical status. Accurate decision-making at this stage of the accident scene determines the post incident quality of life for the victims (5). While the frequency of post collision spinal cord injury is low at 0.7% of recorded patients (3) it remains a real dilemma for prehospital care providers.

A study in the USA retrospectively reviewed clinical data for nearly one million patients with suspected spinal injury. Subsequent detailed medical examination in the emergency departments revealed only 2-3% of patients actually had spinal column and/or cord damage with most injuries being stable. Despite the global movement towards evidence-based practice, many prehospital procedures (including spinal care and management) are based on tradition and practice rather than sound clinical review and evidence. While recent years have seen some research in prehospital care it is imperative that protocols are reviewed to ensure best patient outcomes. When dealing with spinal cord injuries there are two primary considerations to help prevent aggravation or generation of such injuries. Conor in 2015 (6) describes the minimisation of body twisting and the maintenance of spinal lordosis as the primary considerations. Patients trapped within vehicles can be classified according to type; 1- mechanical incarceration, 2- physical incarceration type 1 and 3- physical incarceration type 2. Mechanical incarceration occurs as a result of predominantly minor collisions with the victim unable to exit the vehicle due to mechanical damage (e.g. door mechanism damaged). Physical incarceration type 1 results from higher kinematics of trauma with the victim unable to self-exit due to injuries sustained or general haemodynamic instabilities, such patients require a clear pathway and extrication space to be generated by the extrication crew. Physical incarceration type 2 refers to high impact collisions whereby the victim's body is either compressed or penetrated by vehicle intrusion (7). As a macabre description such patients have traditionally been described as ‘ trapped in hardware’.

In the initial assessment of the victim, the emergency care professional must analyze the mechanism of the trauma and its relationship with the potential damage, which may be inflicted on the victim. Uncontrolled bleeding, airway obstruction, changes in respiratory and hemodynamic patterns, possible neurological, sensory and motor changes, localized back pain and other signs of injury must be examined. All with the aim of establishing assertive and priority decisions defining the immediate and ongoing care required by the victim (4,8). This process is known as the primary survey and determines not only patient care but also the requirement for extrication techniques and equipment. An accurate primary survey helps band victims into one of three categories; critical, stable or unstable (4,8,9). Critical victims are those who face an immediate threat to life either from external forces such as fire, hazardous projects, floods, or who otherwise present with severe medical conditions such as exsanguination, postural asphyxia and cardiopulmonary arrest. Unstable victims are those who present instability at some point within the primary survey examples include hemodynamic instability or breathing complications typically these cannot be resolved wholly onsite rather established by on scene professionals with urgent transport to definitive care where surgical and other interventions are required. Stable patients are identified by absent negative findings in the primary survey and require minor interventions on behalf of rescue professionals, such injuries can be managed on site.

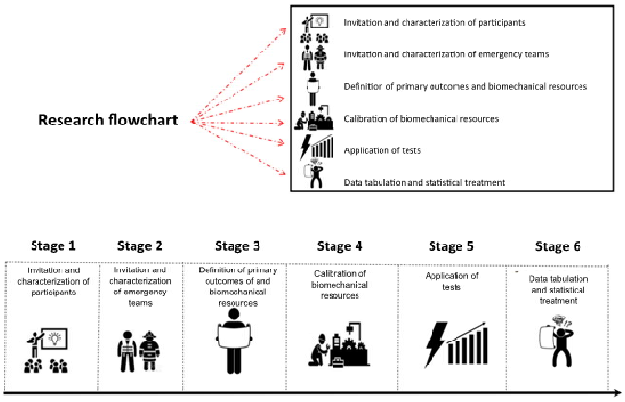
Thus, good clinical care comprises a rapid care plan taking into account the history of the collision, the collision classification, patient clinical status and developing the extrication plan accordingly. Based on the findings described above an extrication is described as immediate, rapid or controlled (4,7). Immediate extrication refers to the identification of immediately life-threatening injuries and supersedes all other interventions (4). Examples of such criteria are postural asphyxia, uncontrolled hemorrhage and cardiac arrest (8,9). When presented with such time critical interventions spinal immobilization becomes secondary to life threatening ABC injuries. Techniques for such evacuations are described in the prehospital literature and include among others the ‘drag technique’ and ‘rauteks Key’ (10). Rapid extrication is related to cases of clinically unstable patients who need to be removed quickly and with minimalist spinal restrictions, as ongoing care within the confines of the vehicle wreckage are unfeasible. Controlled extrication seeks to completely restrict spinal movements, and is applied to stable patients who do not present with ABC injuries (11). Using this technique patients are removed from the vehicle wreckage with the intent of maintaining spinal lordosis, non aggravation of sustained injuries and as a general principle the maintenance of neck, spine and pelvic joints (12). While there are variances from country to country two primary pieces of equipment for controlled extrication include the long or spinal board and the Kendrick Extrication Device. The spinal board is used in a technique known as ‘Zero - angle’ whereby the spinal board is maneuvered into the wreckage space and the patient is manipulated onto the board for removal. Extrication of patient and board then can go ahead with no further movement of the spinal column the aim is to restrict such movements to ‘zero - angles’ with relation the horizontal axis.

The Kendrick Extrication Device (KED) is a proprietary rigid corset, which is applied to a patient with the aim of restricting movement of the spinal column and facilitating a lifting option for such vehicles whereby space is not an issue. Once chosen by the relevant healthcare professional strict instructions regarding use must be observed (13). Recent awareness in the literature suggests the use of the KED may have some detrimental effects such as patient pain, restriction in chest wall movement, prolonged extrication time and a feeling of immobilization which may not be justified (14,15,16). Traditional extrication approaches have been challenged in the more recent literature with the modern focuses being driven towards ABC factors rather than the relatively infrequent spinal instability etiology (17,18,19). Bio- mechanical studies in healthy volunteers have demonstrated in more detail that certain extrication techniques are sub optimal. The purpose of this study is to evaluate whether zero angle extrication or Kendrick extrication should form the basis for future extrication. This topic answers the calls for ‘further investigation’ and will provide data to help refine the fundamental principles of prehospital emergency care.

METHODS

This is a comparative cohort study with exploratory biomechanical analysis of spinal movement, during the use of vehicular extrication techniques. Our research was developed as part of a project to investigate prehospital care techniques for accident victims, based on respect for human dignity and special attention to the protection of research participants. This study is in accordance with the recommendations of Resolution 466 of 2012, of the National Health Council (CNS), it was previously submitted to the Research Ethics Committee of UNIAN/SP and only started after approval by the aforementioned committee with decision number 32787814.0. 0000.5493, with the support of large biomechanics and human movement analysis laboratories in São Paulo. The sample was divided into two groups. The first group was composed of 74 healthy volunteers of both sexes, with different height and weight, who had no knowledge of pre-hospital care, inserted into a vehicle in the driver's position, simulating a victim of a traffic accident (Figure 1).

The second group was composed of 12 teams with 3 members each of prehospital care professionals from different services and institutions with knowledge about basic and/or advanced support levels, with at least five years of practical experience, age, weight and different heights of both sexes. In the first group of volunteers (victims) a randomized controlled trial subdivision was applied, which resulted in two subgroups A and B, with variations between age, weight, height and sex. Group A consisted of 37 volunteers and group B of 37 volunteers. The next step was to randomly choose which interventions each participant would receive. Group A (n=37) underwent extrication at zero angle with a neck brace of the appropriate size for their anatomical standards and a long board, and later they were extracted with a neck brace, KED and long board. Participants in group B (n = 37) were first extracted with a neck brace, KED and long board, and later with a neck brace and long board (zero angle extrication). This process of choosing interventions was carried out by drawing lots. After applying the interventions, the variables were statistically analyzed. All volunteers were extracted once in each technique (zero angle and with KED) by all teams.



Stage 1 – Invitation and characterization of participants: made through contact with the population that frequents parks in the capital of São Paulo (Parque do Tietê, Parque do Ibirapuera, among others) and by regulars of UNIAN/SP. The research was presented and the participants who agreed to participate received guidance from the researchers regarding the study and collection and signed the Free and Informed Consent Term (FICT). Individuals with some type of discomfort or pain before the beginning of the collections or who presented some type of spinal disease were excluded.

Stage 2 – Invitation and characterization of emergency teams: made through direct contact at service units (SAMU, Fire Department of the State of São Paulo, highway concessionaires). The research was presented to the managers of the institutions and later to the PHC professionals from the operational service who agreed to sign the Free and Informed Consent Term (ICF).

Stage 3 – Definition of primary outcomes of analysis and exploratory biomechanical resources. Cervical spine movement was measured using a human motion tracker by wireless kinemetry sensors glued to the clavicular line, chin line, zygomatic line, and frontal line (figure 1 and 2) and Optitrack infrared camera system (Natural Point, USA) that allows the capture of the three-dimensional trajectories of passive reflexive marks placed on the body of each volunteer for kinematic evaluation of the movement. This system consists of 6 infrared cameras, reflective marks and instruments for calibrating the volume of data collection. Also, wireless inertia sensors were used to measure the acceleration (accelerometers) and angular velocity (gyroscopes) of the cervical spine during the different moments of extrication, which were fixed to the head using an elastic headband.Orientation data was collected from each sensor via a Wi-Fi link and sampled at a rate of 40 Hz. Our primary analysis endpoints were: head movement, extrication time, pain and patient comfort through a visual analog scale and analysis of spinal movement restriction by a 3D motion capture system (Spica), based on in video. Each participant's height and weight were recorded before being equipped with the Inertial Measurement Unit (IMU) (Xsens Awinda; Xsens Technologies BV, Enschede, The Netherlands). As secondary outcomes, age, weight, sex, height and length of service of rescuers were analyzed.

Figure 1. Positioning of Sensors for Analysis

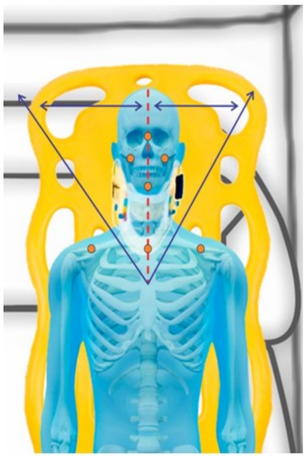


Figure 2. Angles and variations of movement analysis

Stage 4 – Calibration of biomechanical resources. The calibration of the biomechanical equipment was carried out in the Laboratory of Analysis of Human Movement of UNIAN together with the use of a real training vehicle placed inside the laboratory. All test scenarios started with the seat in a standardized position of 52 centimeters away from the steering wheel and 1 degrees of angulation with respect to the steering wheel. Then, the volunteer was instructed to adjust and define, based on their body and individual patterns, the best distance from the seat to the steering wheel, as well as their backrest inclination (figure 3). The real vehicle did not suffer any cuts, as all access routes such as doors and windows were free. The natural opening of the driver's door was used for extrication with KED and the opening of the trunk with lowered seat backrests was used for extrication at zero angle.

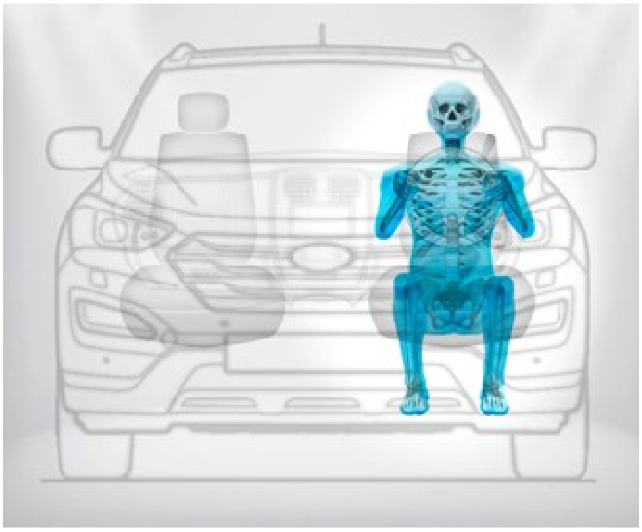
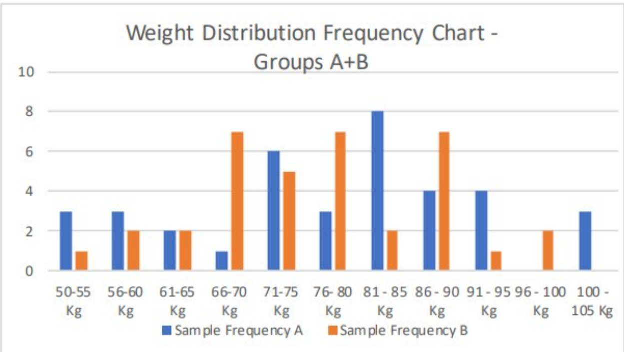


Figure 3. All volunteers started from the driver position

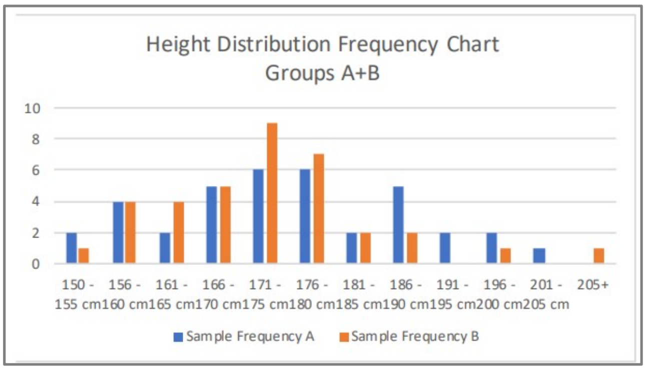
Stage 5 – Application of tests. It took place between January 15, 2022 and June 6, 2022, in the movement analysis laboratory. Upon arriving at the laboratory, both volunteers and rescuers underwent height and weight collection and tabulation of age and sex data. Subsequently, the volunteers (victims) received the application of the sensors and calibration, were inserted inside the vehicle in the driver's position and then the team was started to start the extrication. The extrication was performed in sequence according to the randomization of the group (CONSORT)[20]. Group A received a neck brace, long board, extrication at zero angle through the trunk, and later the neck brace, KED, 90 degree rotation to the driver's door side on a long board. Group B first received the neck brace, KED and 90 degree rotation to the driver's door side on a long board, and later the neck brace, long board, extrication at zero angle through the trunk. Between each collection, there was an interval for repositioning and checking the calibration of the sensors.

The same victim was again inserted into the vehicle in the driver's position and then the same prehospital team performed the second extrication.Also during the extrication phase, the researcher presented a visual analogue discomfort scale (EVA) with a score from 0 to 10 for the volunteer to score discomfort and pain, with values 0 and 1 no discomfort, 2 and 3 mild discomfort, 4 and 5 discomfort or moderate pain, 6 and 7 severe pain, 8 and 9 very severe pain and 10 the worst possible pain. All outcomes analyzed occurred from the first physical contact of the team with the volunteer until their placement on the retractable stretcher of the ambulance. All teams and victims went through both extrications. This was done to ensure consistency between each trial. The prehospital care professionals throughout the collection period extracted 74 volunteers, respecting a maximum of three extrications per collection day.

Stage 6: Data tabulation and statistical treatment. Statistical analyzes were performed using SPSS software (v.20.0). Descriptive statistics (mean, standard deviation, median, minimum and maximum) were calculated. To define the differences between groups A (n = 37) and B (n = 37), Student's t-test for independent samples was applied to compare different groups for the same assessment, to examine basic differences in extrication time , on the degree of head movement, pain and discomfort between these two techniques and further analyzed using magnitude-based Cohen effect size (EET) statistics with modified qualitative descriptors using the following criteria: <0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2– 2.0 = large; and >2.0 very large differences (Hopkins, 2000). The homogeneity of variances was confirmed using the Levene test. In addition, a stepwise multiple linear regression was adopted to examine whether age, sex, weight and height (graphs 1 and 2) of participants influenced the types of extrications tested, as well as which characteristics of emergency workers (age, sex, height , weight and service time) most influenced the extrication techniques. All requirements for this type of analysis were confirmed (absence of collinearity, homoscedasticity, normality of residuals, independence of residuals, absence of outliers and linear relationship between variables). For all procedures, a p value ≤ 0.05 was selected to indicate statistical significance.



Graph 1. Frequency of weight distribution in Groups A (blue) and B (orange)



Graph 2. Height distribution frequency of Groups A (blue) and B (orange)

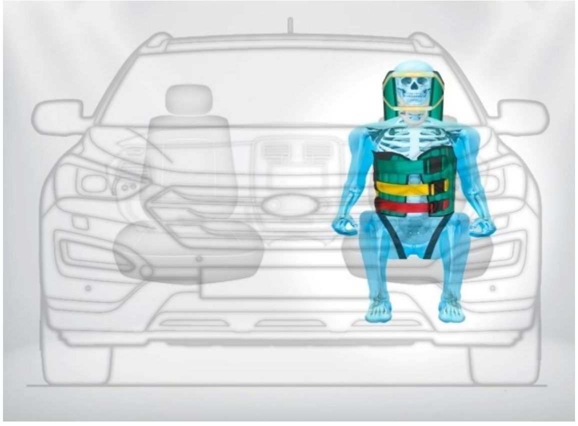


Figura 4. KED use front view

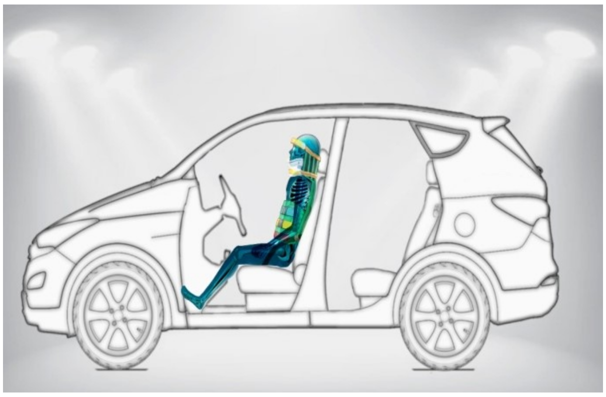


Figura 5. KED employment side view

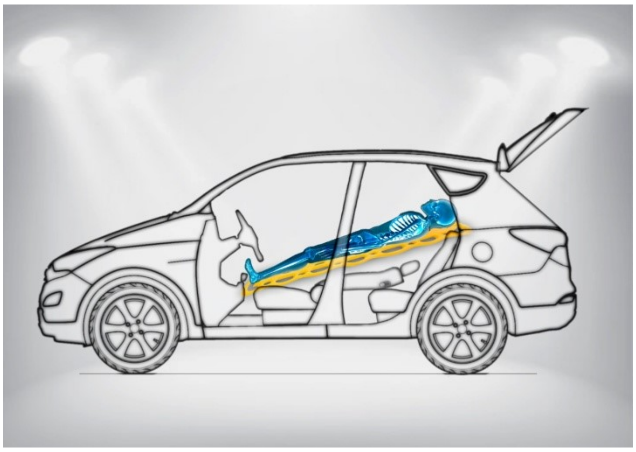


Figura 6. Side view of Extraction at zero angle

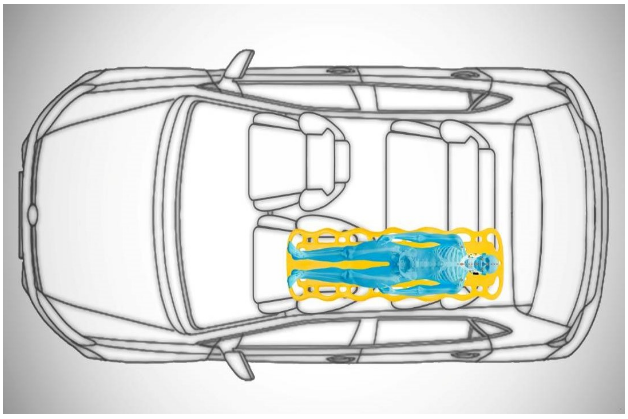


Figura 7. Extraction top view at zero angle

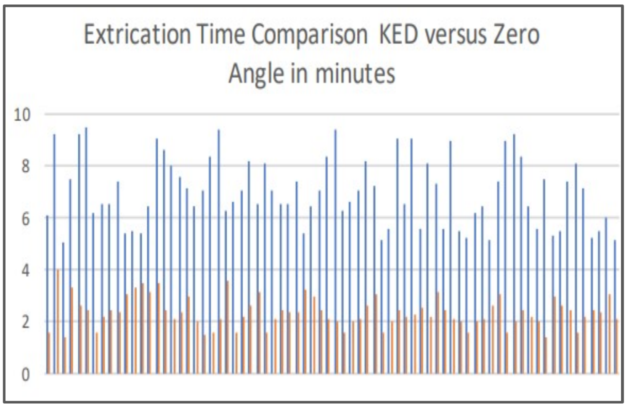
STATISTICAL ANALYSIS

Statistical analyzes were performed using SPSS software (v.20.0). Descriptive statistics (mean, standard deviation, median, minimum and maximum) were calculated.To define the differences between groups A (n = 37) and B (n = 37), the Student's t-test was applied for independent samples and later analyzed using the magnitude-based Cohen effect size (TDE) statistic. with qualitative descriptors modified using the following criteria: <0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2– 2.0 = large; and >2.0 very large differences (Hopkins, 2000). The homogeneity of variances was confirmed using the Levene test. In addition, a stepwise multiple linear regression was adopted to examine whether age, sex, height and weight of participants influenced the types of extrication tested, as well as the characteristics of rescuers that most influenced extrication techniques. All requirements for this type of analysis were confirmed (absence of collinearity, homoscedasticity, normality of residuals, independence of residuals, absence of outliers and linear relationship between variables). A p-value ≤0.05 to indicate statistical significance.

RESULTS

The descriptive statistics of participants (n = 74) and rescuers (n = 36) can be seen in Table 1. Regarding the sex of the volunteers, 45 men participated in the study, 24 in group A and 21 in group B, and 29 women , 13 in group A and 16 in group B. As for rescuers, 21 were men and 15 women. The t-test for independent samples revealed that the means of groups A and B for each analyzed variable are statistically similar, presenting small or trivial effect sizes. It was noticed that the simulated volunteers are representative of the general population, that is, those of average height and weight are the most prevalent, while those who are extremely tall/short or heavy/light are the fewest. The extrication time was longer for group A both for the KED method ($t(72) = 1.091$; $p > 0.05$) and for the zero angle method ($t(72) = 1.872$; $p > 0.05$).

angle; min, minutes; AU, arbitrary units; 95% CI, 95% confidence interval. Multiple linear regression in stages was performed to verify if the age, sex, weight and height of the participants were able to predict any of the variables from the tests applied. The analysis resulted in a statistically significant model for the variable KED angle of movement ($F(4.69) = 3.075$; $p = 0.02$; $R2 = 151$), where height ($\beta = .270$; $t = 2.294$; $p = 0.025$) and weight ($\beta = .393$; $t = 2.598$; $p = 0.011$) are predictors; perception of discomfort felt during the KED extrication method ($F(1.72) = 14.423$; $p > 0.001$; $R2 = 167$), in which the age of the participants ($\beta = 0.409$; $t = 3.798$; $p < 0.001$) contributed significantly for the model; and perception of discomfort felt during the zero angle extrication method ($F(1.72) = 11.944$; $p = 0.001$; $R2 = 142$), suggesting that the age of the participants ($\beta = 0.377$; $t = 3.456$; $p = 0.001$) is predictive. In addition, none of the variables obtained in both extrication tests were significantly influenced by the rescuers' age, weight, height, sex and length of experience (p>0.05).



Graph 3. Comparison of extrication with KED and zero angle in the angle and time variables KED (blue) and AZ (orange)

Table 1. Descriptive statistics of the characteristics of participants and first responders

	Mean	SD	Median	Minimum	Maximum
Participants					
Age	41	14	41	18,00	66,00
Weigh (Kg)	77,32	13,00	78	50,00	105,00
Height (m)	1,75	0,12	1,74	1,50	2,08
First responder					
Age	38	7	37	25	50
Weight (Kg)	77,52	8,58	75,5	66	97
Height (m)	1,78	0,09	1,77	1,67	2,02
Experience (in years)	15	7	14	3	30

Table 2. Univariate differences and effect size of the variables analyzed between participants in groups A and B (t-test for independent samples).KED, Kendrick Device Extrication; AZ, zero angle; min, minutes; AU, arbitrary units; 95% CI, 95% confidence interval

	Group A (*n* = 37)		Group B (*n* = 37)		*t-test*		*d* de Cohen	
	Median	SD	Median	SD	*t-value*	*p*	TDE	IC 95%
Extricationtime - KED (min)	7,17	1,22	6,83	1,40	1,09	00,28	- 0,25 *small*	-0,71; ,20
AZ extrication time (min)	2,49	0,67	2,24	0,45	1,87	00,06	- 0,44 *small*	-0,90; 0,03
KED movement angles (degrees)	18,04	6,60	20,22	5,41	-1,55	00,12	0,36 *small*	-0,10; 0,82
AZ movement angles (degrees)	2,50	0,56	2,46	0,52	0,20	00,84	-0,05 *trivial*	-0,50; 0,41
Pain scale KED (UA)	7,62	1,28	7,78	1,54	-0,49	00,62	0,011 *trivial*	-0,34; 0,57
Pain scale AZ(UA)	3,16	2,11	3,27	1,46	-0,27	00,78	0,06 *trivial*	-0,40; 0,52
Discomfort scale KED(UA)	5,40	1,84	6,13	1,66	-1,78	00,08	0,41 *small*	-0,05; 0,87
Discomfort scale AZ(UA)	3,19	2,24	2,24	1,60	2,08	00,04	-0,48 *small*	-0,95; -0,02

Regarding the subjective perception of discomfort, the mean for group B was higher in the KED method ($t(72) = -1.782$; $p > 0.05$), while for the zero angle method, it was higher for group A ($t(72) = 2.084$; $p > 0.05$). Complete information can be found in Table 2. Table 2. Univariate differences and effect size of the variables analyzed between participants in groups A and B (t-test for independent samples).KED, Kendrick Device Extrication; AZ, zero

CONCLUSION

This study overwhelmingly demonstrates that the standard use of the KED is indeed suboptimal. Furthermore, its use as an extrication tool is based on historical non evidence-based data. The findings show that the age, height, sex of the patients and longevity of EMS rescuer service play no major role in spinal immobilisation care rather, the technique itself is the major determinant of extrication success. The correct technique must therefore be chosen based on the presenting clinical condition and not on the blind mantra of KED application. This is particularly evident for patients who are taller and of greater body mass. Based on such findings the authors recommend that the use of the KED be reviewed by the emergency services. The evidence suggests it should not be the first-preferred technique used for the extrication of victims in road traffic collisions. The data describes how its time to application, level of patient discomfort, and excessive movement of the spinal column may indeed be detrimental to patient outcomes. Conversely, the zero-angle technique has strong indications for preferred use and its adoption as the primary extrication technique considered by emergency service policy makers.

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