

# Comparison of 'chain cabling' and 'roof off' extrication types, a biomechanical study in healthy volunteers

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## Research Article

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# Abstract

## Background:

Following a motor vehicle collision some patients will remain trapped. Traditional extrication methods are time consuming and focus on movement minimisation and mitigation. 'Chain cabling' is an alternative method of extrication used in some Scandinavian countries. The optimal extrication strategy and the effect of extrication methods on spinal movement is unknown. This study compares 'chain cabling' to the established roof removal method of extrication on spinal movement.

## Methods:

Biomechanical data were collected using Inertial Measurement Units on a single healthy volunteer during multiple experiments. The extrication types examined were chain cabling and roof removal. Measurements were recorded at the cervical and lumbar spine, and in the anteroposterior (AP) and lateral (LR) planes. Total movement (travel), maximal movement, mean, standard deviation and confidence intervals are reported.

## Results:

Eight experiments were performed using each technique. The smallest mean overall movements were recorded during roof-off extrication (cervical spine 0.6mm for AP and LR, lumbar spine 3.9mm AP and 0.3 mm LR).

The largest overall mean movements were seen with chain cabling extrication (cervical spine AP 5.3mm. LR 6.1mm and lumbar spine 6.8mm AP and 6.3mm LR).

## Conclusion:

In this study of a healthy volunteer, roof-off extrication was associated with less movement than chain cabling. The movement associated with chain cabling extrication was similar to that previously collected for other extrication types.

# Background

Motor vehicle collisions (MVCs) are a common cause of injury and death [1]. Following an MVC casualties that remain trapped in their vehicles are at risk of more severe injuries and are more likely to die [2].

Extrication is the process of removing casualties with known or potential injuries from their vehicles [2]. Rescue services have developed a wide range of techniques to enable access to casualties and extricate them from their vehicles [3]. Many 'traditional' extrication techniques have developed with a primary focus on movement minimisation because of concerns related to the potential for excessive movement either causing or contributing to secondary spinal injury [4]. Movement minimisation during extrication comes at the expense of time, with extrications on average taking in excess of 30 minutes [5]. Trapped casualties can have significant injuries, some of which may be time dependent [2]. As such some casualties will benefit from rapid extrication and minimal entrapment time [2].

An alternative to traditional extrication techniques with a focus on rapidity of casualty access and extrication termed 'chain cabling' or the 'Norwegian chain method' is used in some areas of Europe [6]. Chain cabling involves attaching anchored chains or strops to the front and rear posts of the damaged vehicle and using a winch to apply traction to the vehicle, therefore reversing the forces and vehicle distortion associated with a frontal collision (see Box 1). A previous study of this method has demonstrated both its acceptance by rescue personnel and its rapidity of successful extrication in a rescue competition environment, with a median extrication time of 12.5 minutes compared to 30 minutes for UK rescue services utilising traditional techniques outside of the competition environment [5, 6].

Potential barriers to adoption of 'chain cabling' include suitability of road environment, availability of equipment and training, and concerns related to potential harmful movement of the casualty during this technique [3]. Previous biomechanical analyses of traditional extrication techniques have identified that the spinal movements associated with each technique were not as expected and have demonstrated the utility of understanding movements associated with commonly used extrication methods [7].

The aim of this study was to quantify the spinal movements associated with 'chain cabling' extrication using the commonly performed 'roof off' type extrication as a comparator.

## **Box 1: Chain Cabling And Vehicle Preparation**

**Technique:** The technique involves the applying of tension to the vehicle containing a trapped casualty using chains or strops. For this study, a fire appliance was positioned at each end of the vehicle with both appliances being secured by their hand brake and chocks. The appliances acted as anchors for an electric winch (Rotzler TR080/6 8 tonne constant pull) or 3.2 ton manually operated (Tirfor) winch secured between the front appliance and the strops. The strops were secured to the central reinforced area of the 'A' post of the car (2) containing the casualty and then to the winch cable and front anchor. The rear strop was secure around the 'C' post of the vehicle and then to the rear anchor (Figure 1).

**Vehicle preparation:** Eight similar vehicles were used with a new vehicle being utilised for each data collection. Relief cuts are made with a cutting tool at 45 degree angle to bottom of the 'A' post and into the sill on each side of the vehicle (Figure 2).

The central transmission tunnel check straps were not unbolted or cut. Further cuts are made through the top of the 'A' posts and the top of the windscreen of the car was cut between the top of the 'A' posts with a cutting tool (A). The vehicle was stabilised by supporting the undercarriage with chocks and vehicle handbrake was engaged.

**Experiment:** Traction was placed across the front strops using the winch. A load cell was used which allowed remote monitoring of the forces being applied and resistance from the vehicle construction so the traction could be halted if pre-specified safety values were exceeded. Traction was applied until the front bumper of the car made contact with the simulated road or if sufficient access was achieved to establish a viable extrication pathway as shown in the photograph below (Figure 3).

## **Methods**

This was an experimental crossover biomechanical study which builds on previous exploratory work and compares spinal movement at both the cervical spine and lumbar spine between 'chain cabling' and 'roof off' extrication types. Roof off was chosen as it is the most frequently delivered technique by rescue services [8].

**Participant:** A single healthy volunteer was recruited to participate in this study and completed all experiments. The participant was briefed on the study, had access to a participant information sheet in advance and completed written informed consent prior to participation.

**Data Collection:** The participant's height and weight were recorded prior to being fitted with the Inertial Measurement Unit (IMU) (Xsens Awinda; Xsens Technologies B.V., Enschede, Netherlands). The characteristics of IMU's and their suitability to extrication research are described elsewhere [9]. The IMU sensor was attached to the head using a headband. The thorax was assumed to be rigid and sensors were positioned over the clavicular notch on the sternum, and over each scapula using a tight-fitting elastic vest. A sensor was positioned on the sacrum by attaching the sensor to shorts using hook-and-loop fastening, to prevent upward travel, and securing the sensor against the body with an elastic belt. The participant was equipped with fire-retardant PPE and a helmet (with visor) to provide head and face protection. Orientation data were

collected from each sensor via a wi-fi link and sampled at a rate of 40Hz. A rigid cervical collar was worn throughout this study as we have previously demonstrated that they reduce movement during extrication [9]. A Laerdal (Laerdal Medical Corp., Stavanger, Norway) Stifneck collar was fitted by a member of the study team trained in its use and in accordance with manufacturer guidance.

**Vehicle preparation:** The vehicle type was pre-specified as a 5-door hatchback as this represents the commonest vehicle type on UK roads [10]. Details of the 'Chain Cabling' car preparation and process can be found in Box 1. For the 'Roof removal' data collection, the car was pre-prepared with the A, B and C posts and the roof removed facilitating a vertical extrication technique. All sharp edges were made safe. The participant was provided with Manual In-Line Neck Stabilisation (MILNS) throughout, the back support of the driver's seat was reclined mechanically and the Long Spinal Board (LSB) inserted to the seat base. The participant was then slid up the board until they were horizontally situated (securely) on the LSB.

**Sample size:** Previous work has provided mean and standard deviations for a range of volunteers undergoing 'roof off' extrication. Acknowledging its limitations, we used a minimally clinically important difference (MCID) derived from cadaveric work (2.7mm) [11]. The power calculation was based on finding an anterior-posterior translational movement of 2.7mm with a significance level of 5% and a power of 80%, giving a sample size per group of 8 extrications.

**Analysis:** The IMU directly measures the segmental orientations from which relative motions can be calculated and reported, by assuming the relative rotations of adjacent vertebrae across the lumbar and cervical region are constant. Maximum excursions (movement from a hypothetical midline) were calculated for anterior/posterior (AP) and lateral (LR) movement of the cervical and lumbar spine, respectively. In addition to reporting maximum excursions (the single largest movement) we report "travel" - the cumulative total of all movements throughout the extrication [12].

Data were captured and analysed using the Biomechanics of Bodies (BoB Biomechanics Ltd, Bromsgrove, UK) software interface before being exported to Excel (Microsoft v. 16.9) and SPSS (IBM v. 25, Armonk NY) for further analysis and reporting. Maximal excursions, travel (total movement), standard deviation and confidence intervals are reported for each extrication type.

The study protocol was reviewed and approved by the University of Coventry Research Ethics Committee (reference number P88416) and the University of Cape Town, Human Research Ethics Committee (reference number 531/2021).

## Results

Data from a total of 16 extrications were successfully collected for analysis; 8 repetitions of chain cabling and 8 using the roof off extrication technique. The results are summarised in Tables 1 and 2, and Figures 4 - 5.

For the cervical spine, the smallest mean overall movements were recorded during roof off extrication (0.6mm for AP and LR). Roof off extrication also produced the smallest mean movements at the lumbar spine (3.9mm AP and 0.3 mm LR).

The largest overall mean movements were seen in the cervical spine movements with the chain cabling extrication (AP 5.3mm and LR 6.1mm). For the lumbar spine, the greatest mean movement was recorded with the chain cabling extrication type (6.8mm AP and 6.3mm LR).

Table 1  
Chain Cabling Maximal Movements:

Trial	Cervical AP (mm)	Cervical LR (mm)	Lumbar AP (mm)	Lumbar LR (mm)	Cervical Roll (°)	Cervical Pitch (°)	Cervical Yaw (°)	Lumbar Roll (°)	Lumbar Pitch (°)	Lumbar Yaw (°)
1	12.4	7.1	10.5	5.0	29.4	20.4	71.7	25.9	16.8	38.2
2	5.5	4.0	4.7	1.1	17.6	12.1	17.2	5.6	8.6	8.9
3	2.5	4.0	11.0	18.1	13.3	7.4	28.6	77.0	59.4	132.2
4	5.3	10.8	12.2	8.4	34.5	12.6	28.1	41.5	39.2	61.5
5	1.2	2.8	2.2	2.0	7.7	4.8	10.6	10.7	2.2	14.8
6	1.9	2.2	1.7	1.1	8.4	4.2	11.8	5.4	3.2	8.7
7	3.0	1.7	3.0	3.0	5.8	7.3	17.4	12.4	9.3	20.9
8	10.3	16.3	8.8	11.4	26.1	38.4	103.7	36.1	41.7	63.5
<b>MEAN</b>	<b>5.3</b>	<b>6.1</b>	<b>6.8</b>	<b>6.3</b>	<b>17.9</b>	<b>13.4</b>	<b>36.1</b>	<b>26.8</b>	<b>22.6</b>	<b>43.6</b>
<b>STDEV</b>	<b>4.1</b>	<b>5.1</b>	<b>4.3</b>	<b>6.0</b>	<b>10.9</b>	<b>11.4</b>	<b>33.6</b>	<b>24.5</b>	<b>21.4</b>	<b>42.0</b>

AP= Anterior posterior, LR = Lateral. Participant height = 186 cm, Mass = 79kg, BMI = 22.8 kg/m<sup>2</sup>

Table 2  
Roof Off Maximal Movements:

Trial	Cervical AP [mm]	Cervical LR [mm]	Lumbar AP [mm]	Lumbar LR [mm]	Cervical Roll [°]	Cervical Pitch [degree]	Cervical Yaw [°]	Lumbar Roll [°]	Lumbar Pitch [°]	Lumbar Yaw [°]
1	1.2	1.1	4.6	0.4	3.3	3.3	1.7	2.2	8.7	2.4
2	0.5	0.8	4.3	0.2	2.3	1.3	1.4	1.1	8.2	2.2
3	1.0	0.6	1.8	0.4	1.7	2.8	2.2	1.8	3.4	3.1
4	0.5	0.4	1.5	0.3	1.2	1.3	1.0	1.2	2.9	1.4
5	0.4	0.4	2.7	0.2	1.1	1.2	1.3	1.3	5.1	2.1
6	0.4	0.6	4.4	0.2	1.6	1.3	1.1	1.1	8.4	1.5
7	0.5	0.3	4.6	0.3	1.0	1.4	1.1	1.6	8.8	1.6
8	0.5	0.7	7.6	0.4	1.9	1.4	1.5	3.2	14.6	3.1
<b>MEAN</b>	<b>0.6</b>	<b>0.6</b>	<b>3.9</b>	<b>0.3</b>	<b>1.8</b>	<b>1.8</b>	<b>1.4</b>	<b>1.7</b>	<b>7.5</b>	<b>2.2</b>
<b>STDEV</b>	<b>0.3</b>	<b>0.3</b>	<b>2.0</b>	<b>0.1</b>	<b>0.8</b>	<b>0.8</b>	<b>0.4</b>	<b>0.7</b>	<b>3.8</b>	<b>0.7</b>

AP= Anterior posterior, LR = Lateral.

## Discussion

This is the first study to report movements at the cervical and lumbar spine during chain cabling extrication. This demonstrates that for a healthy volunteer, roof off extrication was associated with less movement at the cervical and lumbar spine than chain cabling extrication.

Clinical and operational interpretation: There is a conflict in extrication planning and delivery between speed of patient access and extrication, and the casualty movement associated with this. Concerns in relation to excessive patient movement have their origins in the controversial belief that such small movements may contribute to secondary spinal injury. We have previously demonstrated that unstable spinal injuries and cord injuries in isolation are very rare in injured entrapped patients, whereas other time critical injuries (such as head and chest injuries) are much more common [2]. Rescue and clinical services have moved towards increased utilisation of rapid extrication methods over recent years [8]. Considering the similarity in maximal movements across all extrication types (with the exception of self-extrication) it remains appropriate to recommend the quickest deliverable extrication method considering the clinical details and operational environment (Figure 6).

Chain cabling extrication can be considered to consist of two phases: the traction phase where tension is applied to the vehicle (where very little casualty movement occurs) and the casualty removal phase (where the maximal movement occurs). From a bio-mechanical perspective the casualty movements required to facilitate the casualty removal phase of chain cabling are very similar to the 'rapid ex' type method. Consideration should be given to the use of chain cabling as a route of gaining patient access and where appropriate considering an alternative method (e.g. self-extrication) for the casualty removal phase.

Chain cabling is currently delivered routinely by some Scandinavian rescue services and in some areas of Europe. To facilitate chain cabling in other regions would require a significant investment in training, equipment, logistics and process development. When considering chain cabling in comparison to other more routinely delivered methods of extrication it is hard to justify this investment based upon extrication time or minimisation of patient movement where other quicker, established methods with similar movement profiles exist. However, where chain cabling is unique when compared to the other extrication methods is that it has a role in patient disentanglement. This disentanglement occurs when the process of chain cabling physically changes the structure of the vehicle, releasing lower limb entrapment; it may have either a dual role or an advantage over other extrication methods in this respect.

Strengths and weaknesses: A strength of this study is the collection of biomechanical data during dynamic extrication and car movement. We successfully collected data from an appropriate number of extrications to meet the pre-specified power calculation, which allows some confidence in the reported results.

We utilised real vehicles and active-duty rescue personnel to support its internal and external validity. This study was limited by the use of a single uninjured participant and therefore the movements recorded may not be representative of the wider population. Interestingly the movements recorded from our volunteer in roof off extrication type were smaller than those previously reported across a range of healthy volunteers using similar methodology (previously mean 5.2mm AP, 5.11 LR at the cervical spine v's 0.6mm for both from this study) which needs to be considered in the context of the potential external validity of the roof off results [7].

Further work: As the paradigm of absolute movement mitigation continues to be challenged and increasing evidence emerges of extrication methods not performing as expected, those with responsibility for operational guidance and protocol development in the areas of extrication, trauma care and spinal injury must work with patients and their representatives to evolve new evidence-based, patient-centred approaches to extrication.

## Conclusions

In this study of a healthy volunteer, roof-off extrication was associated with less movement than chain cabling. The movement associated with chain cabling extrication was similar to that previously collected for other extrication types. F

## Declarations

This study was carried out in accordance with the relevant guidelines and regulations.

### **Ethics approval and consent to participate**

This analysis was approved by the Coventry University Research Ethics Committee, reference P88416 and the University of Cape Town, Human Research Ethics Committee (reference number 530/2021).

Informed consent was obtained from all volunteers recruited to this study.

### **Consent for publication**

Not applicable.

### **Availability of data and materials**

All data generated or analysed during this study are included in this published article and its supplementary information files.

### **Competing interests**

The authors declare that they have no competing interests

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### **Authors' contributions**

All authors contributed to the conception and study design. Logistics, data collection and reporting by JS, BM, JB, RF & TN. Initial analysis by TN with clinical interpretation by TN, RF, JES, LW and WS. All authors have contributed to and approved the manuscript.

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### **Authors' information (optional)**

Not applicable

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## Figures

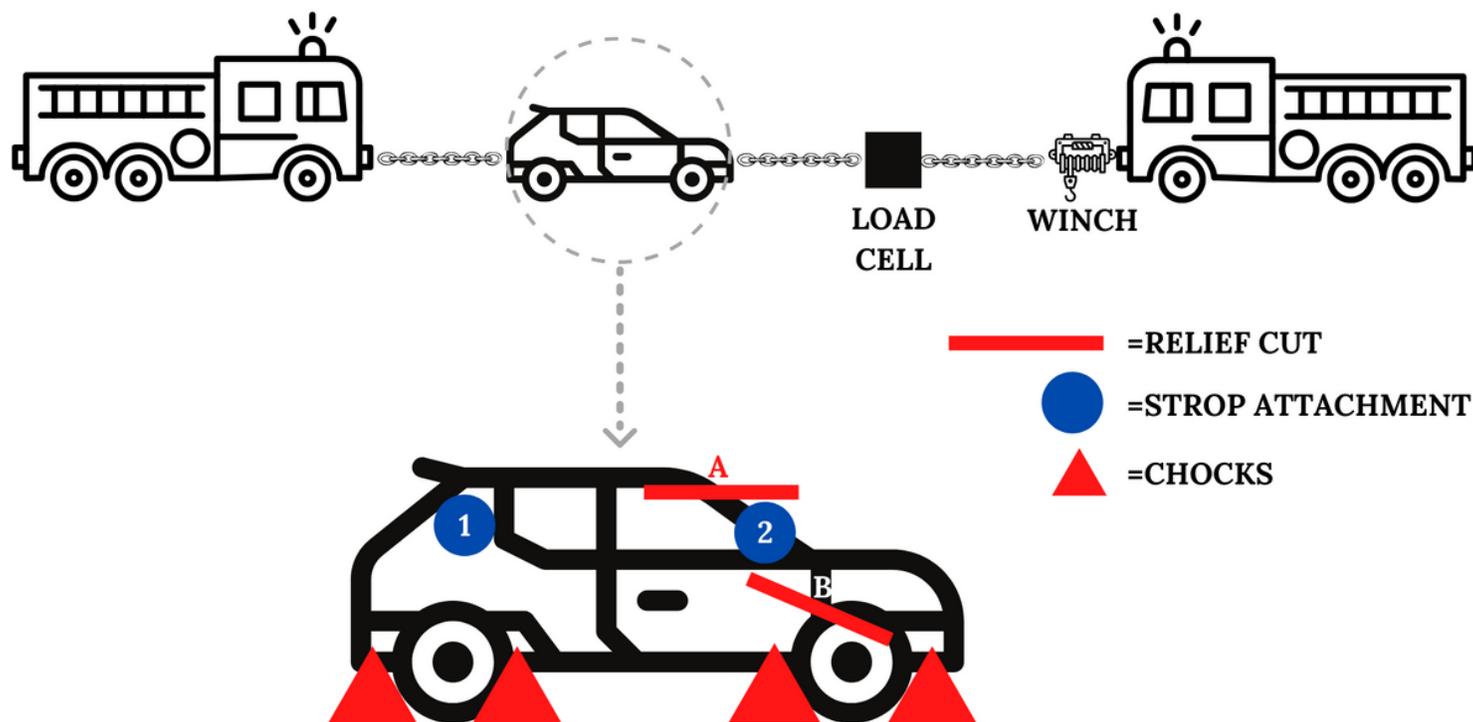


Figure 1

Chain-cabling equipment and vehicle position and orientation



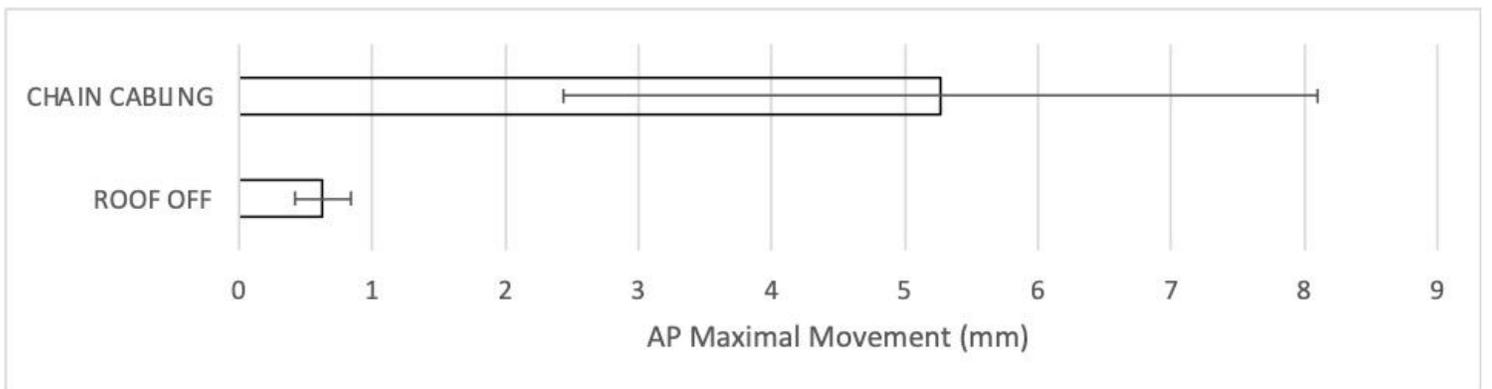
Figure 2

Photograph demonstrating relief cut position



**Figure 3**

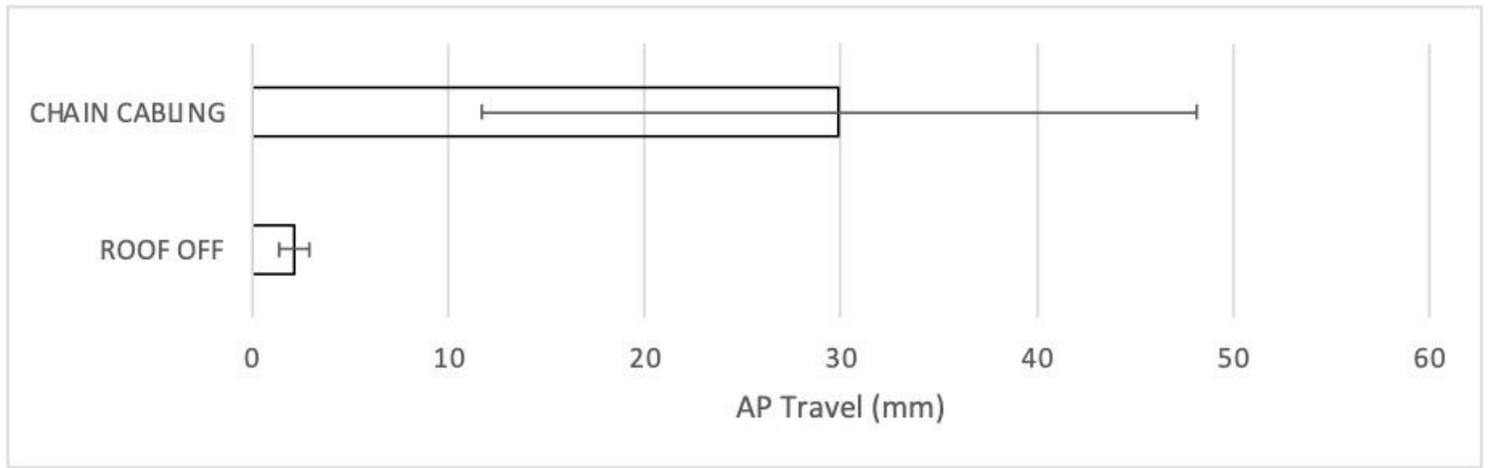
Position of vehicle at completion of traction phase



**Figure 4**

**Cervical AP Maximal Movement\***

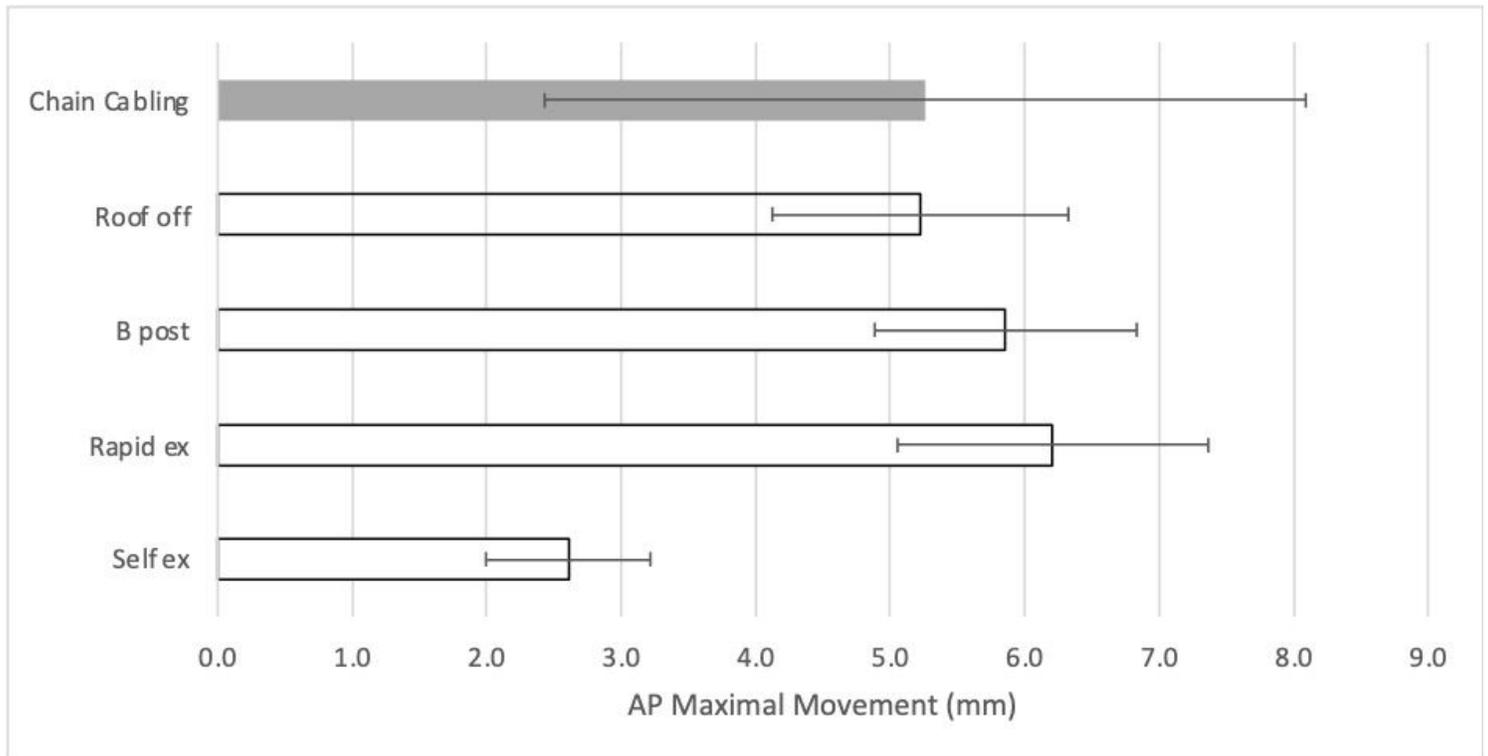
\*Error bars indicate 95% Confidence Intervals



**Figure 5**

**Cervical AP Travel\***

\*Error bars indicate 95% Confidence Intervals



**Figure 6**

**Chain cabling extrication compared to other extrication types\***

**Supplementary Files**

This is a list of supplementary files associated with this preprint. Click to download.

- [chaincablingoriginaldata.xlsx](#)