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RESEARCH REPORT

INVESTIGATION OF STRATEGIES TO PREVENT STRETCHER TRIPPING: A MECHANICAL SIMULATION STUDY

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ABSTRACT

Aim: Little is known about the risk factors associated with stretcher tipping. This study aimed to investigate whether the height of a stretcher is associated with the risk of tipping and to examine strategies to prevent the tipping of a stretcher during transportation.
Methods: This was a mechanical simulation study using Stryker's Power-PRO™ XT. The stretcher and manikin were placed on a board, and the board was inclined at a gradient of approximately 1 degree per second. Tipping was defined as the point at which the weight of the manikin caused one of the wheels to lift off the ground upon applying a specific angle. The tipping angles were measured and examined. The position of the stretcher was varied between supine, seated, high (96cm), middle (66cm), and low (36cm).
Results: In the supine position, the tipping angles were smaller in the order of high, middle, and low position, with a mean (degree) and 95% confidence intervals (CI) of 12.4 (12.2–12.6) for the high position, 18.4 (18.1–18.7) for the middle position, and 26.3 (25.9–26.7) for the low position. In the seat-ed position, the tipping angles were also smaller in the order of high, middle, and low position [11.9 (11.7–12.1) for the high position, 16.2 (15.3–17.0) for the middle position, and 20.2 (19.8–20.6) for the low position, respectively]. Additionally, it was observed that the tipping angles were smaller in the seated position at all stretcher heights compared to the supine position.
Conclusion: The risk of a stretcher tip was found to be greater in the high position compared to the low position and in the seated position compared to the supine position. It is recommended that EMS providers should lower the position of the stretcher as much as possible while ensuring appropriate patient monitoring and care.

INTRODUCTION

Transporting patients from the scene to the hospital is a crucial task for emergency medical service (EMS) providers. This task may need to be performed in unsafe locations such as the second floor of patients' homes, athletic fields, or traffic accident scenes. Patients must be transported to the hospital without causing pain or worsening their condition, and EMS providers are responsible for ensuring safe and prompt transportation in all emergency cases. Accidents such as falls during transport can result in additional harm to the patient and can lead to civil liability for EMS providers.

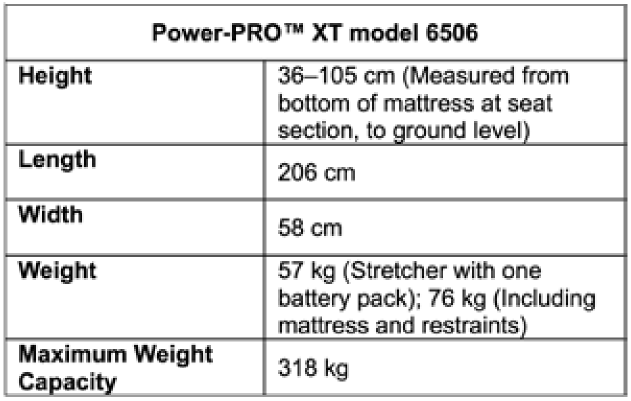
An ambulance stretcher is the primary device EMS uses for transporting patients in the prehospital environment. According to the Fire and Disaster Management Agency in Japan, 21.6% of all accidents during prehospital field activities are related to stretcher operations (Fire and Disaster Management Agency, 2022). Previous studies have revealed that most stretcher tipping frequently occurs during loading & unloading the stretcher from the ambulance, followed by moving the stretcher (Wang, et al., 2009; Yutaka et al., 2021). To date, studies on stretchers have been limited to epidemiological research, and there has been no investigation into the risk factors associated with stretcher tipping.

To address this knowledge gap, we have conducted a mechanical simulation study hypothesizing that the stretcher height is associated with the risk of tipping during transportation. This study aimed to investigate whether the height of the stretcher is associated with the risk of tipping and to examine strategies to prevent the stretcher from tipping during transportation.

METHODS

Study Design and Setting

This mechanical simulation study was conducted in the Hiroshima International University training room on November 15, 2022. The ethical review was waived due to the study design.



Power-PRO™ XT model 6506	
Height	36–105 cm (Measured from bottom of mattress at seat section, to ground level)
Length	206 cm
Width	58 cm
Weight	57 kg (Stretcher with one battery pack); 76 kg (Including mattress and restraints)
Maximum Weight Capacity	318 kg

Table 1: Main specifications of Power-PRO X

The Power-PRO™ XT model 6506 (Stryker, USA) was used in this study. The main specifications of the Power-PRO™ XT are presented in Table 1. The hydraulic system of the stretcher is powered by a battery, enabling the user to easily raise and lower the stretcher using a button.

For this study, a Rescue Randy Manikin (65kg, Simulaids, Inc. USA) was used to simulate the weight and balance of a typical adult male. The manikin was loaded onto a stretcher, and the combination was placed on a board. The board was inclined at a gradient of approximately 1 degree per second.

Tipping was defined as the point at which the weight of the manikin caused one of the wheels to lift off the ground upon applying a specific angle. Tipping angles were measured using a digital inclinometer (DL270LV, STS, Japan) (Figure 1). The position of the

Figure 1: The tipping angles were measured by a digital inclinometer.

stretcher varied between supine, seated, high (96cm), middle (66cm), and low (36cm), and the angle of tipping was measured five times at each position.

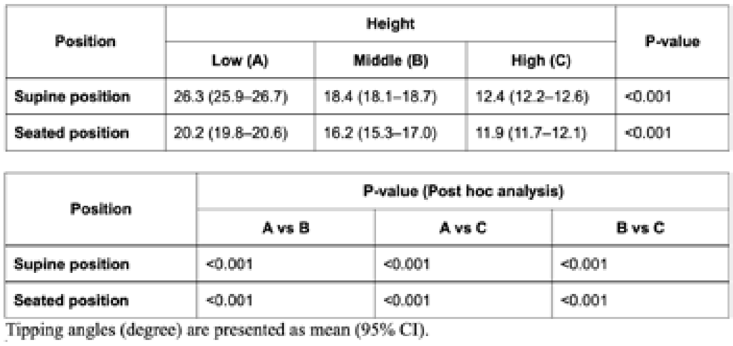
STATISTICAL ANALYSIS

Data was represented as means with confidence intervals. ANOVA was used to compare means for tipping angles by stretcher height, including post hoc analysis with Bonferroni correction for multiple comparisons. Furthermore, a T-test was used to compare means for tipping angles between supine and seated positions by stretcher height. The Kolmogorov-Smirnov test confirmed normal distribution. Data was analyzed with EZR (Kanda, 2013) and P values of <0.05 were considered statistically significant.

RESULTS

TIPPING ANGLES BY STRETCHER HEIGHT

The comparison of tipping angles by stretcher height is shown in Table 2. There were statistically significant differences in the tipping angles between stretcher heights in both supine and seated positions. In the supine position, the tipping angles were smaller in the order of high, middle, and low position [mean (degree) (95% confidence interval (CI)); 12.4 (12.2–12.6) for



Position	Height			P-value
	Low (A)	Middle (B)	High (C)	
Supine position	26.3 (25.9–26.7)	18.4 (18.1–18.7)	12.4 (12.2–12.6)	<0.001
Seated position	20.2 (19.8–20.6)	16.2 (15.3–17.0)	11.9 (11.7–12.1)	<0.001

Position	P-value (Post hoc analysis)		
	A vs B	A vs C	B vs C
Supine position	<0.001	<0.001	<0.001
Seated position	<0.001	<0.001	<0.001

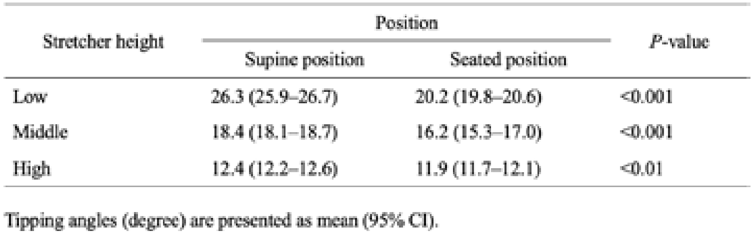
Tipping angles (degree) are presented as mean (95% CI).

Table 2: Comparison of tipping angles by stretcher height.

the high position; 18.4 (18.1–18.7) for the middle; 26.3 (25.9–26.7) for the low position, respectively]. Post hoc analysis revealed significant differences in tipping angles for all combinations. In the seated position, the tipping angles were also smaller in the order of high, middle, and low position [11.9 (11.7–12.1) for the high position; 16.2 (15.3–17.0) for the middle; 20.2 (19.8–20.6) for the low position, respectively].

Tipping angles by position

The comparison of tipping angles by position is shown in Table 3. There were statistically significant differences in the tipping angles between positions in all stretcher heights. The tipping angles were smaller in the seated position compared to in the supine position in all stretcher heights [supine position vs. seated position; 12.4 (12.2–12.6) vs. 11.9 (11.7–12.1) for the high position; 18.4 (18.1–18.7) vs. 16.2 (15.3–17.0) for the middle; 26.3 (25.9–26.7) vs. 20.2 (19.8–20.6) for the low position, respectively]



Stretcher height	Position		*P*-value
	Supine position	Seated position	
Low	26.3 (25.9–26.7)	20.2 (19.8–20.6)	<0.001
Middle	18.4 (18.1–18.7)	16.2 (15.3–17.0)	<0.001
High	12.4 (12.2–12.6)	11.9 (11.7–12.1)	<0.01

Tipping angles (degree) are presented as mean (95% CI).

Table 3: Comparison of tipping angles by position.

DISCUSSION

This simulation study found statistically significant differences in the tipping angles between stretcher height and position. The results indicated that the stretcher was likelier to tip in the high position than in the low position and the seated position than in the supine position. To the best of our knowledge, this is the first study to investigate the association between stretcher height and the risk of tipping.

Previous research on EMS and stretchers has been limited (Wang et al., 2009; Yutaka et al., 2021; Prairie et al., 2017; Armstrong et al., 2017; Studnek et al., 2012), with a focus on adverse events that occur during stretcher operations. One common adverse event is tipping the stretcher while in motion with a patient on it, indicating that patient transfer may be associated with a high risk of tipping. It is, therefore, essential to investigate the risks related to tipping to ensure the safety of both EMS providers and patients. Previous studies have attempted to identify the risk of tipping in patients being transported by EMS using epidemiological methods and interviews with EMS providers (Wang et al., 2009; Yutaka et al., 2021; Prairie et al., 2017). In contrast, the current study sought to understand risks by focusing on the height and position of the stretcher. The present study builds on these prior reports. It extends them by showing significant associations between the height and position of the stretcher and the risk of tipping in simulated conditions.

The mechanisms underlying our findings may be relatively straightforward. The risk of tipping a stretcher while stationary and not moving is determined by the height of the patient's center of gravity, the width of the stretcher's axle, and the angle of inclination. (Figure 2). As such, the higher the height of the stretcher and the seated position rather than the supine position, the higher the patient's center of gravity, resulting in a decreased tipping angle. Additionally, the positioning of the Power-PRO XT's hydraulic assembly, combined with a patient at the stretcher's highest height, may contribute to raising the stretcher's center of gravity. Furthermore, when the stretcher is in motion, various factors come into play, such as the acceleration of the stretcher's movement, changes in the patient's center of gravity due to body movements, and the slope and unevenness of the surface. As a result, increasing the patient's center of gravity further reduces the tipping angle.

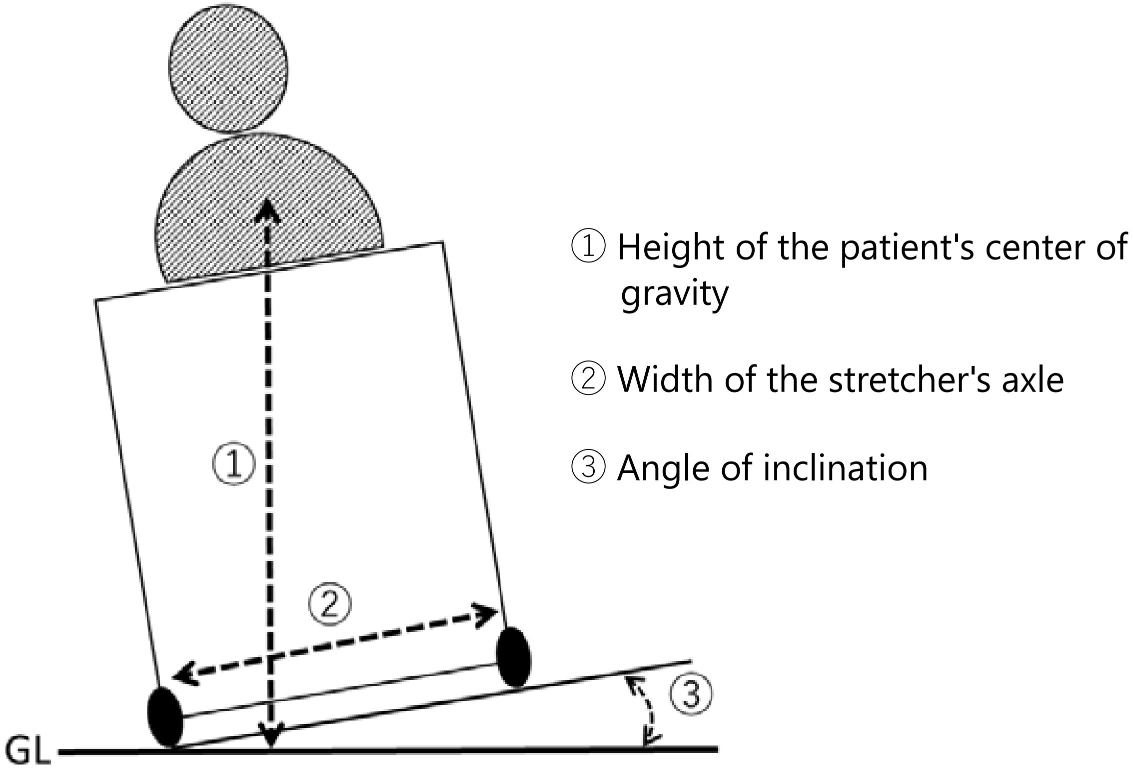


Figure 2: Factors associated with tipping.

The present study provides a strategy for reducing the risk of tipping during patient transport by EMS providers. Specifically, when moving a stretcher with a patient, it is recommended that the stretcher be positioned as low as possible without compromising observation or treatment. Expanding the width of the stretcher would also decrease the risk of tipping; however, since the width of the stretcher is already established as a standard, lowering the stretcher is deemed a practical solution for EMS providers to implement. A previous study reported that many EMS providers moved stretchers in the highest position (Yasuharu et al., 2013). The likely cause for this is that many ambulances require a stretcher to be loaded in a high position. By modifying the design of ambulances and the loading practices of EMS providers, the elevation at which the stretcher is loaded into the ambulance can be reduced, thereby reducing unnecessary positioning of the stretcher in a high position.

LIMITATIONS

Our study has several limitations. First, this study employs a manikin simulation; therefore, the results could be influenced by the manikin's weight, potentially leading to variations from real-world clinical scenarios. As such, the findings may vary if conducted with actual patients. Second, the study was conducted with the stretcher in a stationary position, and the results may have differed if the stretcher had been transported. Finally, the Power-PRO™ XT with the battery was used in this study, limiting the generalizability of the results to other types of stretchers.

CONCLUSION

The height and position of a stretcher have been found to be related to the likelihood of stretcher tipping. A stretcher is more likely to tip in a high position than a low position, and in a seated position than a supine one. Accidents, such as falls that occur during transportation of patients can result in further harm and expose EMS providers to potential civil liability. Therefore, to reduce the risk of tipping during patient transportation, EMS providers should lower the position of the stretcher as much as possible, while ensuring appropriate patient monitoring and care.

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