Enhancing Patient Comfort and Safety in Emergency Medical Transportation: A Comparative Study of Powered vs. Manual Stretchers

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Abstract

Introduction: To assess the impact of powered stretchers in comparison to manual stretchers on both patient comfort and psychological benefits.

Methods: A simulation study with 41 participants compared powered and manual stretchers. Sensors on participants collected X, Y, and Z-axis acceleration data during simulated patient movements. Participants experienced lifting/lowering and loading/unloading. Post-experiment surveys used a 7-point scale to rate comfort during stretcher movements.

Results: The powered stretcher outperformed the manual stretcher in most lifting/lowering and loading/unloading movements, showing significantly lower RMS values, maximum accelerations, and minimum acceleration on each axis. In the Z-axis (vertical direction) acceleration, the powered stretcher demonstrated lower RMS (0.29 m/s^2 vs. 0.73 m/s^2, $p < 0.001$), maximum acceleration (1.60 m/s^2 vs. 2.90 m/s^2, $p < 0.001$), and minimum acceleration (-1.48 m/s^2 vs. -3.30 m/s^2, $p < 0.001$) compared to the manual stretcher. Similar results were observed in the comparison of participant loading/unloading movements, where the powered stretcher exhibited superiority in RMS values, maximum accelerations, and minimum acceleration on each axis. In the Z-axis acceleration, the powered stretcher showed lower RMS (0.32 m/s^2 vs. 0.89 m/s^2, $p < 0.001$), maximum acceleration (2.07 m/s^2 vs. 3.38 m/s^2, $p < 0.001$), and minimum acceleration (-2.34 m/s^2 vs. -3.72 m/s^2, $p < 0.001$) compared to the manual stretcher. Additionally, the powered stretcher significantly improved comfort questionnaire scores compared to the manual stretcher, indicating its potential to alleviate psychological discomfort and anxiety in participants.

Conclusion: Powered stretchers demonstrate significant advantages in reducing patient discomfort and vibrations compared to manual stretchers.

INTRODUCTION

Emergency medical services (EMS) play an important role in saving lives in prehospital settings. EMS personnel are responsible for quick on-site responses, accurate assessments, and timely interventions for patients. The primary objective of this service is to transport the right patient to the right hospital at the appropriate time. Patient movement and transportation are pivotal to ensuring safety. Striking a delicate balance between rapid response and meticulous consideration of a patient's condition and characteristics is essential when EMS personnel engage in patient movement and transportation. (1)

Previous studies have highlighted several risks associated with patient transportation and movement, such as patients falling or tumbling and rescuers experiencing lower back pain. (2–4) To ensure secure and proficient handling, it is essential to provide comprehensive training for EMS personnel and explore innovative transportation techniques. (5, 6) Ongoing efforts are being made to enhance patient safety through advancements in stretcher and transportation device design and modifications. (7, 8) In this context, the development of powered stretchers and automated loading/unloading systems for ambulances has shown promise for reducing the physical strain on operators and minimizing the risk of patients falling from the stretcher. (9, 10)

Considering this background, powered stretchers and automated loading/unloading systems have emerged as promising solutions for ambulances. These advancements aim to decrease physical strain on operators and reduce the risk of patients falling from stretchers. While previous research predominantly focused on the physical stress endured by EMS personnel during stretcher operations, including tasks such as lifting/lowering and loading/unloading patients into/out of an ambulance (11, 12), it is equally crucial to consider the comfort of the patients themselves. Both psychological and physical stresses experienced by patients during movement require careful attention. Ensuring patient comfort during transportation is fundamental to providing appropriate medical care. The anxiety and stress experienced by patients during emergency transportation as well as vibrations during vehicle movement have the potential to adversely affect patients. (13) For instance, it should be prevented to transport patients with conditions such as pelvic fractures by subjecting them to vibrations or other stimuli, as this can worsen the outcome. (14)

Although powered stretchers are known to alleviate the physical demands of operators, their effectiveness in easing the patients' physical burden and anxiety during stretcher operations remains uncertain. Therefore, this study aimed to compare the physical and psychological benefits experienced by patients using powered and manual stretchers.

METHODS

Study Design

This comparative crossover simulation study included a total of 41 participants. This study was approved by the Niigata University of Health and Welfare Ethics Committee (Approval No. 19067–230620). The study’s objective, significance, methods, and rules for opt-out were explained to the participants in a written format and verbally beforehand. The participants were requested to provide written informed consent, which they agreed to do.

Participants

Thirty-one firefighters with EMS qualifications and ten third-year students from the paramedical department of a university participated in the study. These participants were recruited from two fire departments: 15 male and 1 female firefighter from one department (Group A), and 11 male and 5 female firefighters from another department (Group B). In addition, 10 male students were recruited from a university institution (Group C).

While the participants had experience operating stretchers, they had little to no experience of being on a stretcher as a patient or being accommodated in an ambulance. Specifically, student participants had no prior experience in these areas. Participants lay on the stretcher like patients and underwent lifting and lowering movements as well as being accommodated in the ambulance. Additionally, since the participants were familiar with stretcher operation, they took turns operating the stretcher during the experiment. They were randomly selected and each participant operated the stretcher only once for these actions in each verification. Essentially, participants were assigned the responsibility of operating the stretcher after completing their role as simulated patients. When operating the stretcher, the participants performed the usual stretcher operations during regular emergency activities. However, in this verification, operators' activities were not evaluated.

Instruments

We compared four types of stretchers: 1) Power-PRO™ XT Model 6506 (Stryker, Inc., USA), 2) Matsunaga GT (Matsunaga, Inc., Japan), 3) Exchange model 4070 (Ferno Japan, Inc., Japan), and 4) Scud Mate (Ferno Japan, Inc., Japan). The Power PRO™ XT was used as the powered stretcher. The others were used as manual stretchers. The characteristics of all stretchers are listed in Supplementary Table 1.

Powered stretcher

Power PRO™ XT utilizes an electric hydraulic elevation system that combines the motor and hydraulic components. Precise elevation adjustments can be achieved by pressing the "elevation and depression button," allowing for optimal positioning during the procedures. The Power-LOAD™ Electric Fastener not only reduces the physical strain on emergency personnel but also diminishes the risk of patient falls during the loading and unloading processes. This feature enhances patient transportation safety within the vehicle, and is specifically designed to prevent patients from falling off the stretcher. Power-LOAD™ is an internal loading and unloading device intended for use with a Power PRO™ XT stretcher. One of the ambulance vehicles was outfitted with power-LOAD™. The ambulance was used to elevate and lower the participants on a powered stretcher, a task requiring only one operator.

Manual stretcher

Other ambulances were equipped with antivibration pedestals to reduce the stretcher vibrations. A manual stretcher requires the involvement of more than two operators. Owing to the presence of vibration-damping platforms commonly installed in Japanese ambulances, operators must exert a slight force when inserting a manual stretcher. Similarly, when the stretcher is pulled out of the vehicle, instances have been observed in which the stretcher's legs do not fully extend because of the need to lower the stretcher from a higher position, causing it to fall to its lowest position. (15) Matsunaga GT was verified by group A, Scad Mate by group B, and Exchange by group C.

Evaluations

Study protocol

In the validation process, participants initially laid down on the stretcher at its lowest setting, after which the operator secured them in place by tightening the provided straps. For the manual stretcher, operators manually lifted it, whereas for the powered stretcher, the elevation button was pressed to raise it to the highest position and then lowered back to the lowest position. These movements were then evaluated. In another validation trial, the participants were placed on the stretcher at the highest setting. The stretcher was fully loaded into the ambulance and then completely pulled out of the ambulance, with these actions being assessed. Both powered and manual stretchers were evaluated for these activities.

Measurements

The impact of these actions on the psychological comfort or discomfort of the participants was assessed through a questionnaire survey along with the perception of vibrations from the patient's perspective. Further insights into the participants' kinematics of the stretcher were captured using WitMotion sensors (WitMotion Shenzhen Co., Ltd., China), a device whose reliability has been demonstrated in other studies. (16) These sensors were positioned strategically at the anterior waist.

Measurement for vibrations

Acceleration data representing the horizontal direction (X-axis), depth direction (Y-axis), and vertical direction (Z-axis) movements were extracted from the angular orientation and linear acceleration of the anterior waist. These data were wirelessly transmitted via Bluetooth 2.0 to computer software for analysis. The subsequent analysis included determining both the upper and lower peak accelerations and other accelerations as well as calculating the root mean square (RMS) acceleration. The RMS acceleration values were averaged from a series of operations conducted from the beginning to the end of each validation. RMS accelerations, which represent the square root of the average of the squared instantaneous values of a waveform over one cycle, provide a comprehensive assessment of the overall impact of movement (Supplementary Fig. 1). The RMS was calculated using the following formula: (17)

$$RMS = \sqrt{\frac{\left(x1^2 + x2^2 + x3^2 + \cdots + xn^2\right)}{n}}$$

Questionnaire survey

In each post-experiment questionnaire survey, participants rated their comfort level during stretcher movements on a 7-point scale ranging from comfortable (-3) to uncomfortable (3). The survey comprised 23 evaluation items, each featuring contrasting adjectives for comfort and discomfort. The survey was conducted using the Semantic Differential method. (18) The 23 adjective-based questions were selected based on existing research. (19)

Statistical analysis

We observed that the continuous variables examined did not follow a normal distribution; therefore, we opted to use the paired nonparametric Wilcoxon signed-rank test as a suitable analytical approach to compare the two groups. When comparing the vibrations experienced by participants during the operation of the four types of stretchers, we conducted a non-parametric repeated measures ANOVA for the four groups, followed by post-hoc testing using the non-parametric version of the Tukey-Kramer test, known as Steel-Dwass multiple comparisons. Based on our pilot study, the mean difference between the two groups was 0.4, and the standard deviation was 0.8. With a significance level of $p = 0.05$ and a power value of 0.8 at an effect size of 0.2, we estimated that the study required 34 participants in each group. All data were analyzed using the JMP Pro software (version 17; SAS Institute, Cary, NC, USA). For each analysis, the null hypothesis was tested at a two-sided significance level of $p < 0.05$.

RESULTS

Participants mean age and height (standard deviation [SD]) were 30.4 (11.5) years and 172.3 (6.9) cm, respectively. The acceleration data extracted from certain participants representing movements are shown in Supplementary Fig. 2 for the X-axis (horizontal direction), Supplementary Fig. 3 for the Y-axis (depth direction), and Supplementary Fig. 4 for the Z-axis (vertical direction). The initial segment of the waveform corresponded to the time at which the participant lying on the stretcher was lifted or loaded inside the ambulance. The latter part of the waveform represents instances in which the participant lying on the stretcher was lowered or unloaded from the ambulance.

Comparison of participant lifting/lowering movements

Figure 1 (left) illustrates the results of accelerations in each direction, with detailed data presented in Table 1. We confirmed the superiority of Powered stretcher in most comparisons, although we did not find significant differences in the following comparisons between the two groups: For the minimum acceleration on the X-axis (horizontal direction), as well as the maximum and minimum accelerations on the Y-axis (depth direction), and the maximum acceleration on the Z-axis (vertical direction), no significant differences were observed between the Powered and Exchange groups. Moreover, there was no significant difference in Y-axis (depth direction) minimum acceleration between the Powered group and the Matsunaga GT group. Similarly, there was no significant difference in Y-axis (depth direction) minimum acceleration between the Powered and the Scad Mate groups.

Table 1
Comparison of participant lifting and lowering movements on the stretcher

	Powered	Manual	*p*-value	Manual stretcher			*p*-value#
				Matsunaga GT	Exchange	Scad Mate	
	(n = 41)	(n = 41)		(n = 15)	(n = 10)	(n = 16)	
Acceleration of the X-axis							
RMS (m/s^2)	0.13 (0.11–0.19)	0.47 (0.31–0.57)	< 0.001	0.28* (0.22–0.32)	0.44* (0.36–0.54)	0.57* (0.51–0.87)	< 0.001
Maximum (m/s^2)	0.65 (0.46–1.26)	1.97 (1.39–2.80)	< 0.001	1.33* (0.98–3.78)	1.95* (1.37–2.51)	2.44* (1.93–3.60)	< 0.001
Minimum (m/s^2)	-0.75 (-1.25–-0.51)	-2.00 (-2.80–-1.30)	< 0.001	-1.35* (-1.97–-0.90)	-2.10 (-2.88–-1.40)	-2.74* (-3.56–-2.29)	< 0.001
Acceleration of the Y-axis							
RMS (m/s^2)	0.22 (0.18–0.25)	0.46 (0.32–0.58)	< 0.001	0.37* (0.31–0.53)	0.35* (0.31–0.47)	0.61* (0.51–0.7)	< 0.001
Maximum (m/s^2)	1.21 (0.93–1.56)	2.21 (1.62–3.01)	< 0.001	2.29* (1.51–3.08)	1.69 (1.36–2.21)	2.76* (1.90–3.76)	< 0.001
Minimum (m/s^2)	-1.39 (-1.73–-0.86)	-2.19 (-2.84–-1.44)	< 0.001	-2.21 (-2.70–-1.28)	-1.44 (-2.29–-1.18)	-2.60 (-3.91–-2.00)	< 0.001
Acceleration of the Z-axis							

RMS, root mean square.

Statistically significant differences were observed in the comparison among the Powered, Matsunaga GT, Exchange, and Scad Mate stretchers.

* Statistically significant differences were observed compared to the powered stretcher as a reference by Steel Dwass multiple comparisons, $p < 0.05$.

	Powered	Manual	*p*-value	Manual stretcher			*p*-value#
				Matsunaga GT	Exchange	Scad Mate	
	(n = 41)	(n = 41)		(n = 15)	(n = 10)	(n = 16)	
RMS (m/s²)	0.29 (0.25–0.36)	0.73 (0.47–0.89)	< 0.001	0.45* (0.38–0.70)	0.60* (0.50–0.83)	0.88* (0.81–1.33)	< 0.001
Maximum (m/s²)	1.60 (1.31–2.17)	2.90 (1.78–4.51)	< 0.001	1.79* (1.61–3.11)	2.67 (1.59–4.30)	4.35* (2.87–5.63)	< 0.001
Minimum (m/s²)	-1.48 (-1.77–-1.19)	-3.30 (-4.88–-2.22)	< 0.001	-2.18* (-3.30–-1.59)	-3.00* (-4.70–-2.37)	-4.50* (-7.31–-3.68)	< 0.001

RMS, root mean square.

Statistically significant differences were observed in the comparison among the Powered, Matsunaga GT, Exchange, and Scad Mate stretchers.

* Statistically significant differences were observed compared to the powered stretcher as a reference by Steel Dwass multiple comparisons, $p < 0.05$.

When comparing powered and manual stretchers, the RMS values, maximum accelerations, and minimum acceleration on each axis were significantly lower in the powered group compared to the manual stretcher group.

- *In the X-axis (horizontal direction) acceleration*

the RMS (median: 0.13 m/s², [25–75%: 0.11–0.19] vs. 0.47 m/s² [0.31–0.57], $p < 0.001$), maximum acceleration (0.65 m/s² [0.46–1.26] vs. 1.97 m/s² [1.39–2.80], $p < 0.001$), and minimum acceleration (-0.75 m/s² [-1.25– -0.51] vs. -2.00 m/s² [-2.80– -1.30], $p < 0.001$) were lower in the powered compared to the manual stretchers.

- In the Y-axis (depth direction) acceleration

the RMS (0.22 m/s², [0.18–0.25] vs. 0.46 m/s² [0.32–0.58], $p < 0.001$), maximum acceleration (1.21 m/s² [0.93–1.56] vs. 2.21 m/s² [1.62–3.01], $p < 0.001$), and minimum acceleration (-1.39 m/s² [-1.73– -0.86] vs. -2.19 m/s² [-2.84– -1.44], $p < 0.001$) were lower in the powered compared to the manual stretchers.

- In the Z-axis (vertical direction) acceleration

the RMS (0.29 m/s², [0.25–0.36] vs. 0.73 m/s² [0.47–0.89], $p < 0.001$), maximum acceleration (1.60 m/s² [1.31–2.17] vs. 2.90 m/s² [1.78–4.51], $p < 0.001$), and minimum acceleration (-1.48 m/s² [-1.77– -1.19] vs.

-3.30 m/s² [-4.88– -2.22], $p < 0.001$) were lower in the powered stretcher compared to the manual stretcher.

Comparison of participant loading/unloading movements

Figure 1 (right) illustrates the results of accelerations in each direction, with detailed data presented in Table 2. In the same manner as the results in the comparison of participant lifting/lowering movements, we confirmed the superiority of powered stretcher in most comparisons, although we did not find significant differences in the following comparisons between the two groups: For the minimum acceleration on the X-axis (horizontal direction), as well as the maximum and minimum accelerations on the Y-axis (depth direction), and the maximum acceleration on the Z-axis (vertical direction), no significant differences were observed between the Powered and Exchange groups. Moreover, there was no significant difference in Y-axis (depth direction) minimum acceleration between the Powered and the Matsunaga GT groups. Similarly, there was no significant difference in Y-axis (depth direction) minimum acceleration between the Powered and the Scad Mate groups.

Table 2
Comparison of participant loading and unloading movements on the stretcher

	Powered	Manual	*p*-value	Manual stretcher			*p*-value#
				Matsunaga GT	Exchange	Scad Mate	
	(n = 41)	(n = 41)		(n = 15)	(n = 10)	(n = 16)	
Acceleration of the X-axis							
RMS (m/s^2)	0.19 (0.16–0.24)	0.56 (0.41–0.78)	< 0.001	0.45* (0.35–0.54)	0.61* (0.50–0.71)	0.89* (0.50–0.71)	< 0.001
Maximum (m/s^2)	0.97 (0.73–1.58)	2.19 (1.82–3.37)	< 0.001	2.07* (1.38–2.69)	1.99* (1.56–3.21)	3.08* (1.97–4.99)	< 0.001
Minimum (m/s^2)	-1.76 (-2.10–-1.25)	-2.38 (-3.55–-1.85)	< 0.001	-1.95* (-2.38–-1.70)	-2.85 (-3.63–-1.80)	-3.46* (-4.72–-1.93)	< 0.001
Acceleration of the Y-axis							
RMS (m/s^2)	0.27 (0.24–0.34)	0.73 (0.56–0.99)	< 0.001	0.82* (0.65–1.02)	0.65* (0.41–0.83)	0.58* (0.50–1.14)	< 0.001
Maximum (m/s^2)	1.65 (1.39–2.14)	3.32 (2.16–4.41)	< 0.001	3.37* (3.18–4.91)	2.85 (1.60–4.50)	2.41* (1.99–3.65)	< 0.001
Minimum (m/s^2)	-2.34 (-3.33–-1.56)	-2.83 (-4.20–-2.00)	0.025	-3.14 (-4.72–-2.60)	-2.35 (-4.14–-1.45)	-2.75 (-4.29–-1.98)	< 0.001
Acceleration of the Z-axis							

RMS, root mean square.

Statistically significant differences were observed in the comparison among the Powered, Matsunaga GT, Exchange, and Scad Mate stretchers.

* Statistically significant differences were observed compared to the powered stretcher as a reference by Steel Dwass multiple comparisons, $p < 0.05$.

	Powered	Manual	*p*-value	Manual stretcher			*p*-value#
				Matsunaga GT	Exchange	Scad Mate	
	(n = 41)	(n = 41)		(n = 15)	(n = 10)	(n = 16)	
RMS (m/s²)	0.32 (0.26–0.40)	0.89 (0.72–1.14)	< 0.001	0.84* (0.64–0.96)	0.73* (0.62–0.88)	1.14* (0.90–1.24)	< 0.001
Maximum (m/s²)	2.07 (1.47–3.11)	3.38 (2.64–4.55)	< 0.001	2.93* (2.32–4.40)	3.13 (2.39–6.14)	3.86* (3.07–4.87)	< 0.001
Minimum (m/s²)	-2.34 (-3.33–-1.56)	-3.72 (-5.29–-3.14)	< 0.001	-3.39* (-4.31–-2.58)	-3.90* (-5.06–-2.68)	-5.02* (-5.77–-3.26)	< 0.001

RMS, root mean square.

Statistically significant differences were observed in the comparison among the Powered, Matsunaga GT, Exchange, and Scad Mate stretchers.

* Statistically significant differences were observed compared to the powered stretcher as a reference by Steel Dwass multiple comparisons, $p < 0.05$.

When comparing powered and manual stretchers, the RMS values, maximum accelerations, and minimum acceleration on each axis were significantly lower in the powered stretcher group compared to the manual stretcher group.

- *In the X-axis (horizontal direction) acceleration*

the RMS (median: 0.19 m/s², [25–75%: 0.16–0.24] vs. 0.56 m/s² [0.41–0.78], $p < 0.001$), maximum acceleration (0.97 m/s² [0.73–1.58] vs. 2.19 m/s² [1.82–3.37], $p < 0.001$), and minimum acceleration (-1.76 m/s² [-2.10– -1.25] vs. -2.38 m/s² [-3.55– -1.85], $p < 0.001$) were lower in the powered compared to the manual stretchers.

- In the Y-axis (depth direction) acceleration

the RMS (0.27 m/s², [0.24–0.34] vs. 0.73 m/s² [0.56–0.99], $p < 0.001$), maximum acceleration (1.65 m/s² [1.39–2.14] vs. 3.32 m/s² [2.16–4.41], $p < 0.001$), and minimum acceleration (-2.34 m/s² [-3.33– -1.56] vs. -2.83 m/s² [-4.20– -2.00], $p < 0.001$) were lower in the powered compared to the manual stretchers.

- In the Z-axis (vertical direction) acceleration

the RMS (0.32 m/s², [0.26–0.40] vs. 0.89 m/s² [0.72–1.14], $p < 0.001$), maximum acceleration (2.07 m/s² [1.47–3.11] vs. 3.38 m/s² [2.64–4.55], $p < 0.001$), and minimum acceleration (-2.34 m/s² [-3.33– -1.56] vs.

-3.72 m/s² [-5.29– -3.14], $p < 0.001$) were lower in the powered stretcher compared to the manual stretcher.

Questionnaire survey for lifting and lowering movements

Figure 2 shows the results of the questionnaire survey conducted after stretcher lifting and lowering, with the detailed data presented in Supplementary Table 2. In the questionnaire, we confirmed the significance of the powered stretcher for most items. The comfort confidence items "Comfortable," "secure," "like," "smooth," and "relaxing," showed that the Powered stretcher was significantly more comfortable than the other stretchers. However, responses to questions such as "Easy or tired," "Nausea-free or nauseous," "Stationary or swing," "Not dizzy or dizzy," " "Not painful or painful," and "Wish to continue riding or wish to get off" did not exhibit significant differences between the powered and exchange groups. Similarly, the question item "Not rocked up and down or rocked up and down" showed no significant difference between the powered and Matsunaga GT groups.

Questionnaire survey for loading and unloading movements

Figure 3 presents the results of the questionnaire survey conducted after stretcher loading and unloading, with detailed data provided in Supplementary Table 3. In the questionnaire, we evaluated the significance of the powered stretcher in various aspects. We confirmed its significance for most items. The comfort confidence items "Comfortable," "secure," "like," "smooth," and "relaxing," showed that the Powered stretcher was significantly more comfortable than the other stretchers. However, for the questionnaire items "Nausea-free or nauseous" and "Not dizzy or dizzy," no significant differences were observed between the powered stretcher group and both the Matsunaga GT and Exchange groups. Similarly, no significant differences were found between the Powered and Exchange groups for the questions 'Comfortable or uncomfortable,' 'Weakly or powerful,' and 'Feeling good or feeling bad.' Additionally, there were no significant differences between the Powered and Matsunaga GT groups for the 'Soft or hard,' and 'Sleep-inducing or wakeful' questions.

DISCUSSION

This study was the first to examine the comfort and safety of stretchers in emergency medical care. We conducted a comparative crossover simulation study with 41 participants who experienced the situation of being patients lying on powered and manual stretchers. We collected acceleration data and conducted a comfort questionnaire. According to the results, the powered stretcher significantly reduced the RMS values, maximum accelerations, and minimum accelerations in most axes compared with the manual stretcher. This suggests that the powered stretcher could effectively reduce the vibrations and shocks experienced by the participants on the manual stretcher. Additionally, the powered stretcher significantly increased the scores for most items on the comfort questionnaire compared with the manual stretcher. This indicates that the powered stretcher could alleviate the psychological discomfort and anxiety experienced by the participants in the manual stretcher. The present study demonstrates that a powered stretcher has the potential to enhance the quality and safety of emergency medical care by reducing both the physical burden and psychological anxiety experienced by patients.

The present study revealed the tangible discomfort experienced by patients, as evidenced by the RMS values and maximum and minimum accelerations during lifting and lowering maneuvers. The ISO2631 [17] standard offers guidelines for comfort assessment, indicating that an RMS acceleration (m/s^2) below 0.315 m/s^2 generally avoids patient discomfort. Discomfort may be slight within the range of 0.315 to 0.63 m/s^2, moderate within 0.5 to 1 m/s^2, and noticeable within 0.8 to 1.6 m/s^2. Substantial discomfort may emerge within the 1.25 to 2.5 m/s^2 range, while exceeding 2 m/s^2 may lead to extreme discomfort. This study focused on lifting and lowering actions using powered stretchers and revealed significantly reduced RMS values in the z-axis (vertical) direction. Median RMS values stood at 0.29 m/s^2 (0.25–0.36) for powered stretchers and 0.73 m/s^2 (0.47–0.89) for manual counterparts. According to these guidelines, powered stretchers are expected to increase patient comfort, whereas manual stretchers may induce moderate discomfort.

The questionnaire results suggest an overall preference for the powered stretcher, as indicated by the positive responses on multiple items. Specifically, the comfort confidence items "Comfortable," "secure," "like," "smooth," and "relaxing," showed that the Powered stretcher was significantly more comfortable than the other stretchers. These aspects contribute to a positive user experience with a powered stretcher. However, the Powered stretcher did not excel in any aspect. In particular, there were no significant differences between the powered stretcher group and the other groups in several terms. This indicates that these factors did not influence participants’ preferences. Nevertheless, the Powered stretcher consistently outperformed the other groups in both the lifting/lowering and loading/unloading movements. These results demonstrate the superior performance of the powered stretcher under different scenarios. To corroborate the results of the questionnaire survey, another important finding of our study was the difference in vibrations between the manual and powered stretchers. Manual stretchers cause significantly higher vibrations, which could worsen the conditions of emergency patients, such as cerebral hemorrhage or pelvic fractures. (20) Moreover, manual stretchers were associated with more adverse events, such as patient falls, which compromised patient safety and comfort. (15, 21, 22) Therefore, powered stretchers and fastening systems could be better alternatives, as they could reduce the operator’s physical strain and improve patient outcomes. (23)

Limitations

This study had several limitations. First, the participants were healthy firefighters and university students. However, their experience of lying on the stretcher and being operated on as a patient is rare, making it a novel experience for them. This could potentially affect the perception and evaluation of the stretcher. Additionally, we did not inquire about the participants' weight or BMI, especially considering the sensitivity of female participants. Acceleration may vary according to the participant’s body characteristics.

Second, three types of manual stretchers were used for validation. Although there are various types of manual stretchers, we selected three, which are commonly used in Japan. However, it is unclear whether these stretchers are representative of manual stretchers. Other manual stretchers may exist with less vibration, similar to a powered stretcher.

Third, in the validation of the manual stretcher, not all the participants experienced all three manual stretchers. Specifically, in the validation of the Exchange stretcher, there were only 10 university students who were younger and fewer in number than the other participants.

Lastly, participants operated the stretchers themselves. Although we instructed the operators to lift and lower the stretchers in the usual manner, there were individual differences in the proficiency and methods of stretcher operation. The proficiency and methods of the operators may have influenced the vibrations and evaluations. For example, a skilled operator may minimize vibrations during lifting and lowering operations. Additionally, different operating methods may result in variations in the stability and usability of the stretcher. Therefore, these factors may constrain the generalizability of the results.

CONCLUSION

Powered stretcher shows significant advantages in minimizing patient discomfort and vibrations compared to manual stretchers in emergency medical settings. This study underscores the potential for enhancing patient safety and quality of care. In conclusion, the powered stretcher has emerged as a promising tool for improving the quality and safety of patient transportation in prehospital settings.

DECLARATIONS

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We would like to express our gratitude to all the participants for their cooperation. The statistical analysis in this study was conducted by the author.

1. Ethics approval and consent to participate:

This study was approved by the Niigata University of Health and Welfare Ethics Committee (19067-230620).

2. Consent for publication:

Not applicable

3. Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

4. Competing interests:

The authors declare that they have no conflicts of interest.

5. Report format:

All the methods were performed in accordance with relevant guidelines and regulations

6. Funding:

This study did not receive any specific grants from funding agencies in the public, commercial, or not-for-profit sector.

7. Inform consent:

Written informed consent was obtained from the participants for the publication of this study, according to the Niigata University of Health and Welfare Ethics Committee.

8. Authors' Contributions

GT and YT had full access to all data in the study and took responsibility for the integrity of the data and accuracy of the data analysis. Study Concept and Design: YT. Data acquisition: GT, TN, and YT. Analysis and interpretation of data: All authors. Drafting of the manuscript: GT and YT. Statistical analysis: YT and SN. Study supervision: SN and YY. All the authors have read and approved the final manuscript.

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Figures

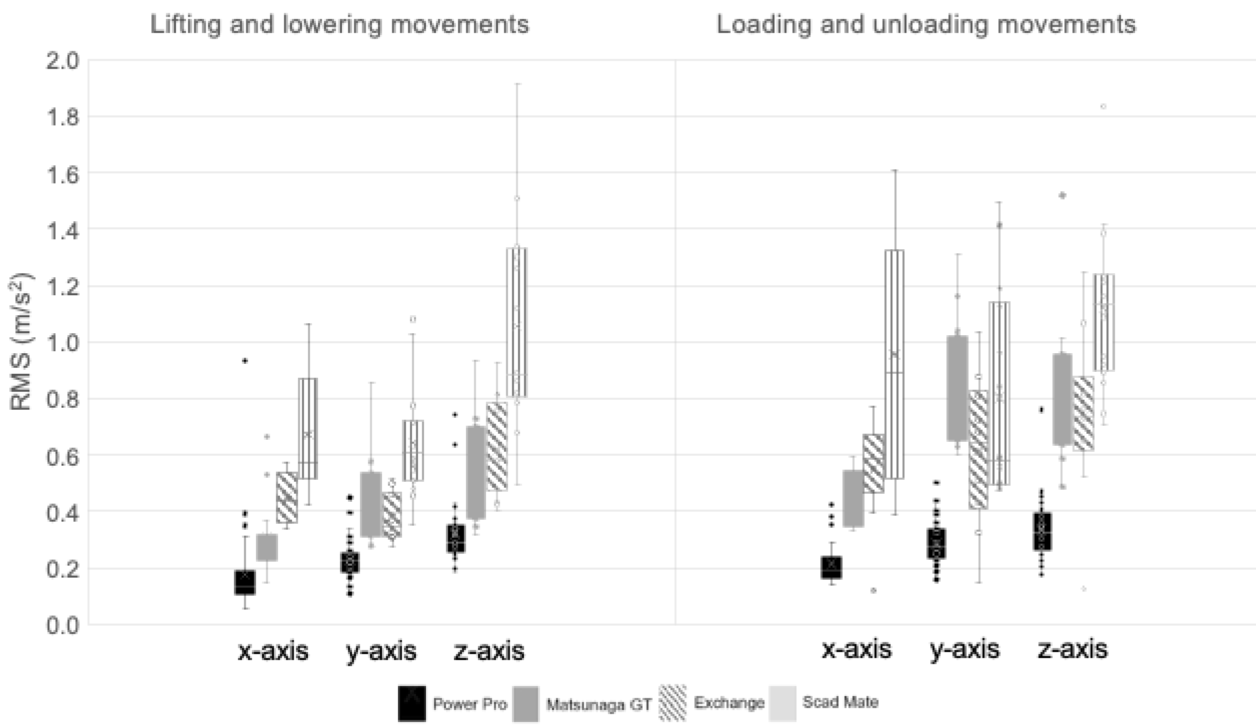

Figure 1

Acceleration during participant lifting/lowering and loading/unloading movements.

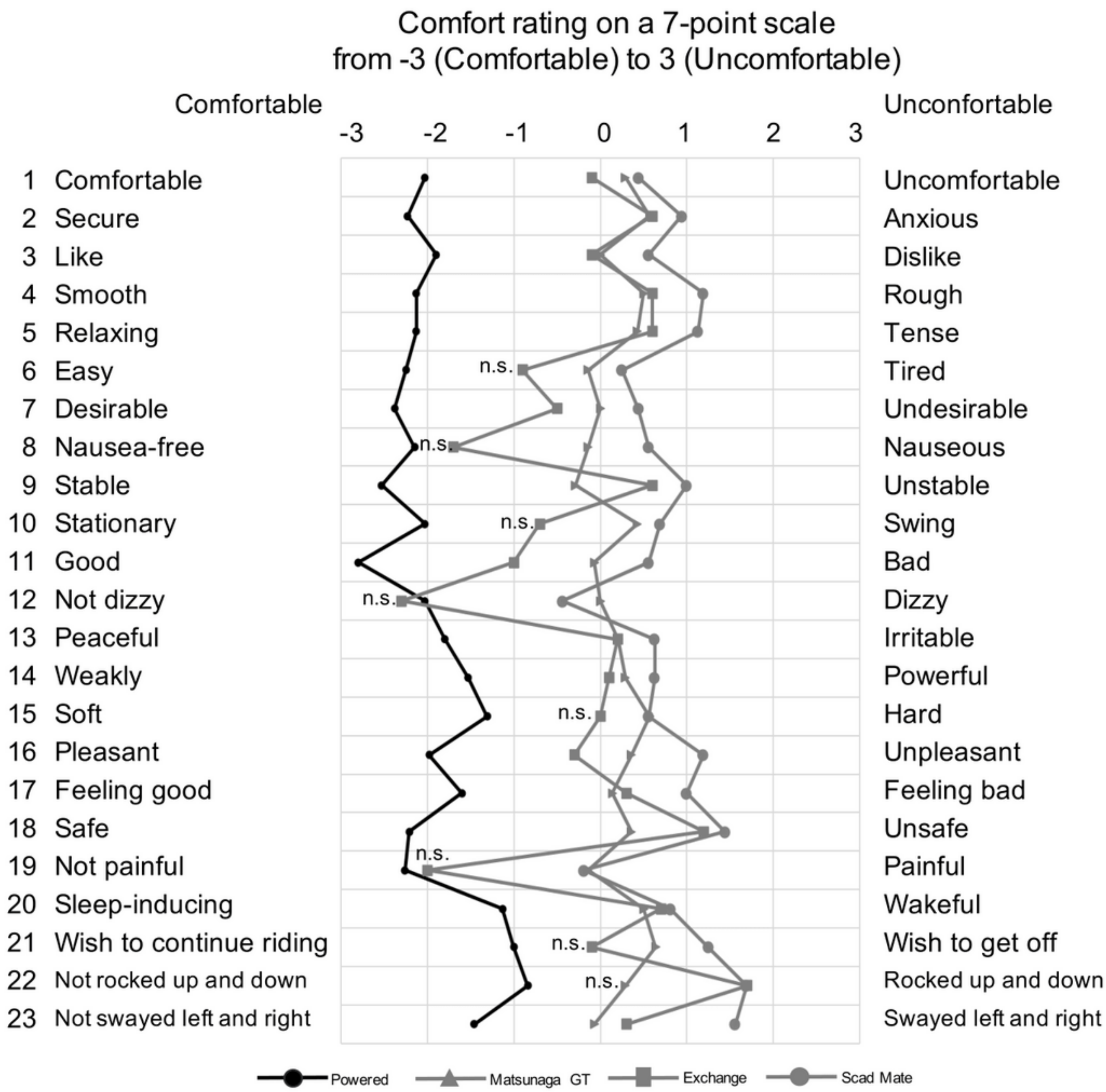

Figure 2

Inspirations after stretcher lifting and lowering motions.

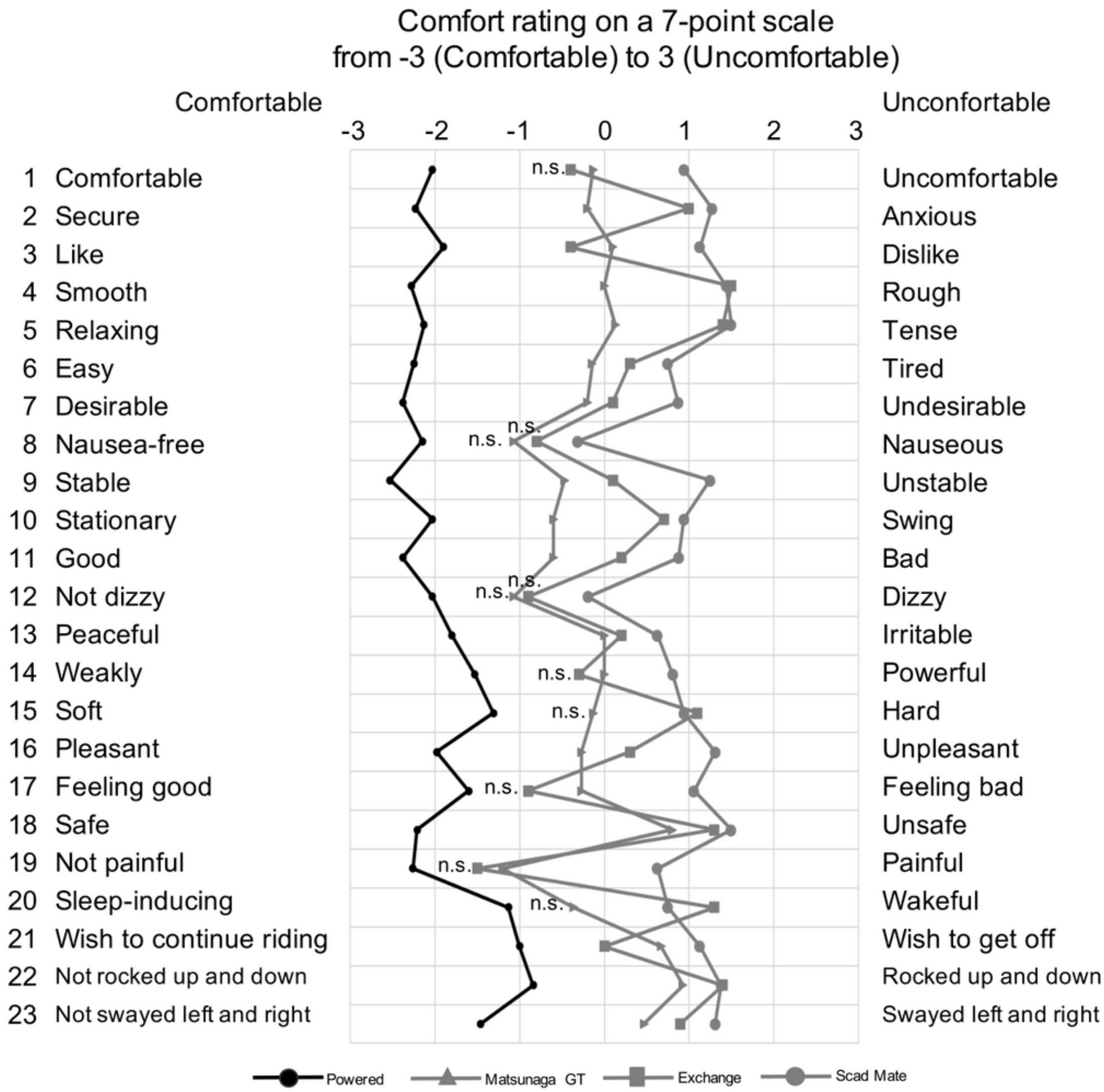

Figure 3

Inspirations after stretcher loading and unloading motions.

Supplementary Files

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