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Ergonomic Hazards and Musculoskeletal Strain Among Paramedics During In-Transit Trauma Care: A MyoMotion and EMG Study

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ABSTRACT

Paramedics encounter numerous occupational hazards, including ergonomic, physical, psychological, and biochemical risks. This work examines the types of discomfort paramedics experience during in-ambulance procedures, highlighting their adverse influence on musculoskeletal loading and providing a basis for ergonomic and organizational improvements. Non-invasive MyoMotion and EMG assessments were used to evaluate musculoskeletal strain during common medical interventions performed both at rest and while the vehicle was in transit.

Initial findings indicated that paramedics frequently faced musculoskeletal overload due to sustained, awkward body positions while treating trauma patients. Several of these postures—particularly those adopted during ambulance movement—posed a substantial injury risk. Designing ambulance interiors with ergonomic principles in mind may help decrease injury risks during medical procedures.

Keywords: Paramedic, Ambulance, Occupational risk factors, Body movement, EMG, Injury

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Introduction

The core responsibility of a paramedic is to deliver professional care in situations involving sudden health or life-threatening emergencies. Their role demands rapid, accurate decision-making supported by a wide medical skill set. Key tasks include evaluating a patient's condition and performing the medical interventions needed to safeguard life and health [1]. Because paramedics operate in varied environments, the hazards they face differ considerably, influencing their overall occupational risk. These risks fall into four primary groups—physical, chemical, biological, and psychosocial—while some authors additionally include ergonomic factors. Ergonomic hazards mainly impact the musculoskeletal system, especially the spine, since interventions often involve lifting or maintaining strained, non-neutral positions [2–4].

Emergency medical services (EMS) represent a field where staff are routinely subjected to physical demands and exposure to danger [3–6]. Consequently, creating ergonomic working conditions is essential for improving comfort and reducing injury likelihood. Global data point to a growing shortage of paramedics; turnover in the United States and Germany is close to 10 % annually [7–9]. Overall, 54 % of paramedics consider leaving EMS within a year, and 46 % report dissatisfaction with their work environment [5].

Because ambulance work varies greatly, the paramedic's workstation is not easily defined. Paramedics often provide care without spatial limitations, particularly for trauma victims. Around 44 % of active patient-care time occurs inside the ambulance cabin during treatment procedures [10]. An ambulance is formally described as a transport vehicle dispatched to sudden medical or accident events, intended to deliver care and move injured or ill individuals to a healthcare facility. It is also used for general and inter-hospital transport. Such vehicles are crewed by trained EMS teams and form a core component of emergency response systems [1, 3, 11, 12]. Given that a large proportion of paramedic tasks occur within the vehicle, this study concentrated on the in-

ambulance workstation [11, 13, 14]. Musculoskeletal issues in paramedics are frequently linked to muscle fatigue from prolonged or repetitive medical procedures, including those performed with low muscular activation. Fatigue typically results from overloading the musculoskeletal system; thus, lowering physical demand and strain in the work environment may help limit or prevent musculoskeletal disorders [15, 16]. Accurate methods for evaluating muscle load and fatigue are therefore crucial [17].
This study was guided by the hypothesis that recognizing in-ambulance discomfort experienced by paramedics is essential for developing recommendations related to ambulance layout and organizational practices. Prior work by the authors [18] facilitated the creation of a methodology to gather data on musculoskeletal fatigue and the physical demands posed by constrained postures during trauma-related medical procedures inside the ambulance.

Materials and Methods

Data acquisition methodology

A major difficulty in collecting information that accurately represents musculoskeletal loading, fatigue, and posture during ambulance-based medical tasks is the requirement to rely solely on non-invasive tools that do not disrupt the paramedic's natural movement. These tools must also record data continuously without restricting the paramedic's performance. Two methods met these criteria. The first was surface electromyography (sEMG), which records muscle electrical activity using external electrodes and provides insight into fatigue. The second method captured the motion of specific body segments during medical tasks, enabling an assessment of positional strain during routine procedures. Kinematic measurements were performed in stationary conditions, whereas EMG readings were obtained while the ambulance was in motion.
This article presents selected findings from procedures carried out on a simulated trauma patient. Because generalizable outcomes depend on adequate sample size, it is important to note that this investigation was intentionally designed as a pilot study aimed at pinpointing major ergonomic concerns in paramedic work. Data from a single participant were used to develop a methodological framework that will later be applied to a larger cohort. One of the primary limitations in research of this type is the restricted availability of ambulances and trained paramedics. As in other countries, Polish ambulances typically operate continuously, which limits their research accessibility. Each experiment required renting an ambulance for a designated period, which generated extra logistical and financial burdens and reduced paramedic availability, as they are usually engaged in emergency care. Consequently, larger-scale studies in real-life conditions involve complex planning, which is currently underway. For the purposes of this preliminary investigation, the focus remained on one experienced paramedic.
The study was carried out in an ambulance belonging to the Independent Public Healthcare Institution RM-MEDITRANS Emergency Medical Services and Sanitary Transport Station in Siedlce. The participant was a male paramedic, 39 years old, 178 cm tall, weighing 80 kg, with no history of musculoskeletal issues. His occupational health check dated June 29, 2023, confirmed no contraindications. He performed selected tasks both when the ambulance was stationary and when it was in transit. Overall, seventeen commonly performed in-ambulance procedures were initially identified through consultation with experienced staff, but only five trauma-related activities are presented here. All tests were conducted in a Mercedes ambulance configured according to the standards used by the Siedlce service. The procedures involved an advanced medical simulator **(Figure 1)**. Each activity took place under real driving conditions. The pilot design made it possible to detect various discomforts encountered by EMS personnel during work.

Figure 1. Test setup – interior of a fully equipped ambulance with a stretcher-mounted medical simulator.

The project (9/2022) received approval from the Research Ethics Committee of the Warsaw University of Technology on November 23, 2022.

Medical procedures

Analyzed medical procedures

This study reports findings from five procedures: lower-limb immobilization (P1), upper-limb immobilization (P2), thermal insulation (P3), control of lower-limb bleeding (P4), and trauma assessment (P5). The paramedic executed these tasks in both standing and seated positions, frequently employing a flexed posture. Limb stabilization was performed using Kramer wire splints. Following Pott's rule, immobilization involved stabilizing at least two adjacent joints—above and below the injury—without attempting fracture reduction, preventing movement of bone fragments, and limiting pain at the site [19].

Thermal protection consisted of wrapping the patient securely in a thermal (emergency) blanket to reduce heat loss or avoid excessive warming. The blanket's purpose is to maintain a stable thermal environment for the patient [19].

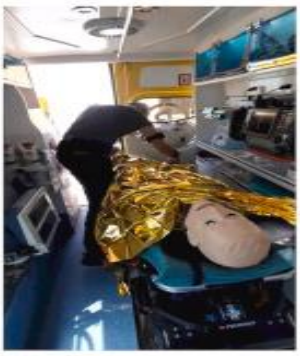
The "stopping of lower limb hemorrhage" procedure was completed while the paramedic stood beside the patient. During this task, the femoral artery was compressed using the paramedic's right leg, while a dressing was applied to the bleeding area. To carry this out, the paramedic had to maintain a strained posture, raising the right leg and leaning toward the wound [19].

The trauma examination followed current guidelines and was performed in a standing position. The assessment involved checking vital parameters and scanning the patient for injuries that could pose immediate danger. The paramedic used both visual inspection and tactile assessment. After recording vital signs, the following regions were evaluated in order: head, neck, chest, abdomen, pelvis, lower limbs, upper limbs, back, and buttocks [19].

Figure 2 illustrates sample body positions adopted by the paramedic while performing these procedures.

a)

b)



c)

d)

e)

Figure 2. The paramedic performing: a) upper-limb immobilization, b) lower-limb immobilization, c) thermal insulation, d) control of lower-limb bleeding, e) trauma assessment.

The most frequent trauma-related procedures in Eastern Mazovia EMS

The Independent Public Healthcare Institution RM-MEDITRANS Emergency Medical Services and Sanitary Transport Station in Siedlce delivers emergency care and health-promotion services across the eastern Mazovia region of Poland. The service area, overseen by the Siedlce EMS, includes the counties of Siedlce, Sokołów, Łosice, Mińsk, Garwolin, and Węgrów. Within this territory, 24 EMS teams operate—5 specialist units and 19 basic teams [20].

According to statistics from the Command Support System of the National Medical Rescue Service, which documents all EMS responses nationwide, the Siedlce EMS performed 39,705 interventions in 2022, translating to roughly 1654 calls per team per year, or approximately 5 missions daily. Injuries accounted for 17.43 % of these cases (n = 6920).

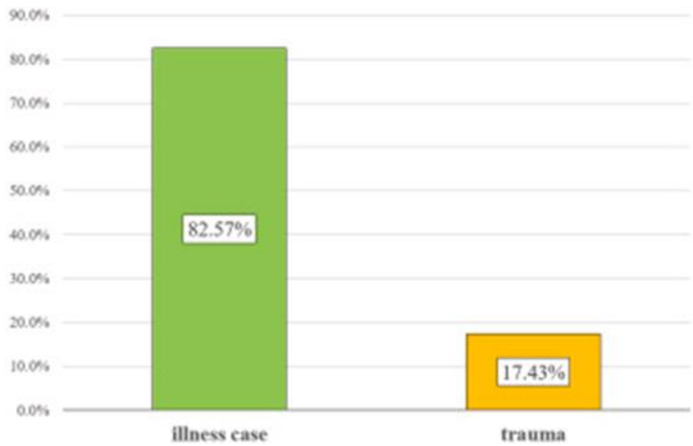


Figure 3. displays the percentage distribution of incident categories for 2022.

The RM-MEDITRANS Emergency Medical and Sanitary Transport Station classifies its interventions using the ICD-9 system, allowing procedures—diagnostic, therapeutic, surgical, and billing-related—to be coded consistently.

Table 1. lists selected trauma-related medical procedures performed on-site by EMS teams in eastern Mazovia between January 1 and December 31, 2022.

Code	Procedure Description	n	%
89.79	Other physical examination	6295	90.97%
89.71	Patient evaluation to determine treatment plan and decision to start or withhold emergency interventions	5452	78.79%
89.07	History taking (subjective examination)	3713	53.66%
89.540	Monitoring of basic vital signs	2136	30.87%
93.5000	Management of head injuries	906	13.09%
93.5004	Management of upper extremity injuries	361	5.22%

93.5022	Lower extremity immobilization	360	5.20%
93.5020	Upper extremity immobilization	323	4.67%
93.521	Application of cervical collar	271	3.92%
93.5017	Spinal immobilization using a spine board	254	3.67%
93.5006	Management of lower extremity injuries	240	3.47%
93.57	Application of wound dressing (other types)	227	3.28%
93.5001	Management of facial injuries	143	2.07%
93.542	Application of Kramer splint	63	0.91%
93.5002	Management of nasal injuries	56	0.81%
93.5005	Management of upper extremity injuries (alternative code)	46	0.66%
93.5007	Management of lower extremity injuries (alternative code)	29	0.42%
93.549	Application of other immobilization splints	28	0.40%
93.573	Application of hydrogel dressing	25	0.36%
93.5021	Upper extremity immobilization (alternative code)	22	0.32%
93.5008	Management of chest injuries	21	0.30%
93.5011	Management of abdominal injuries	18	0.26%
93.5023	Lower extremity immobilization (alternative code)	13	0.19%
93.5009	Management of anterior chest wall injuries	13	0.19%
93.5010	Management of posterior chest wall injuries	11	0.16%
93.5015	Management of ear injuries (external, middle, and/or inner)	4	0.06%
93.5012	Management of pelvic injuries	4	0.06%
93.564	Application of tactical/combat tourniquet	4	0.06%
93.5018	Spinal immobilization using vacuum mattress	3	0.04%
93.5019	Immobilization using Kendrick Extrication Device (KED)	3	0.04%
93.572	Application of hemostatic tactical gauze (rapid-action hemorrhage control)	3	0.04%
93.5016	Management of ear injuries (external, middle, and/or inner) – duplicate code	2	0.03%
93.5025	Application of pelvic stabilization belt/sling	2	0.03%

Based on these data, trauma assessments (history-taking and physical examination) were the most commonly executed procedures for injured patients. These were followed by trauma-management tasks and various limb-immobilization techniques. Thermal-insulation steps do not appear in ICD-9 and are therefore absent from the list, although they remain recommended in situations involving hypothermia risk, hyperthermia, or severe multi-system trauma.

Recording motion kinematics during medical tasks

Ranges of motion of anatomical joint angles examined

The experimental setup included measurements of 31 anatomical joint angles on both the right and left sides of the body. The angles assessed are provided in **Table 2**.

Table 2. Summary of anatomical angles examined.

No.	Body Part and Movement Measured
1	Neck flexion (cervical flexion)
2	Neck right side bending (cervical lateral flexion – right)
3	Neck right rotation (cervical axial rotation – right)
4	Lower back flexion (lumbar flexion)
5	Lower back right side bending (lumbar lateral flexion – right)
6	Lower back right rotation (lumbar axial rotation – right)
7	Mid-back flexion (thoracic flexion)
8	Mid-back right side bending (thoracic lateral flexion – right)

9	Mid-back right rotation (thoracic axial rotation – right)
10	Left elbow flexion
11	Right elbow flexion
12	Left shoulder total flexion (combined glenohumeral + scapulothoracic)
13	Right shoulder total flexion (combined glenohumeral + scapulothoracic)
14	Left shoulder glenohumeral flexion
15	Right shoulder glenohumeral flexion
16	Left shoulder abduction
17	Right shoulder abduction
18	Left shoulder external (lateral) rotation
19	Right shoulder external (lateral) rotation
20	Left hip flexion
21	Right hip flexion
22	Left hip abduction
23	Right hip abduction
24	Left hip external (lateral) rotation
25	Right hip external (lateral) rotation
26	Left knee flexion
27	Right knee flexion
28	Left knee external (lateral) rotation
29	Right knee external (lateral) rotation
30	Left knee abduction (valgus)
31	Right knee abduction (valgus)

Measuring equipment

Motion analysis was conducted using the Noraxon MyoMotion system. This technology integrates inertial sensors with wireless data transmission and software capable of capturing and analyzing 3D movement.

Research procedure

Joint-angle determination followed the neutral/zero medical method, which assumes that in a standing posture, all joints are positioned at anatomical zero—even when geometric angles differ. For instance, although the ankle joint forms a geometric angle of 90°, the anatomical angle is defined as zero.

Each MyoMotion sensor includes X, Y, and Z axis markings. Sensors were affixed so that, in upright stance, the X-axis label aligned vertically with the direction of gravitational force. Inertial units were attached to the paramedic's body according to the MyoMotion protocol to record accelerations. **Figure 4** illustrates sensor placement, with details listed in **Table 3**.

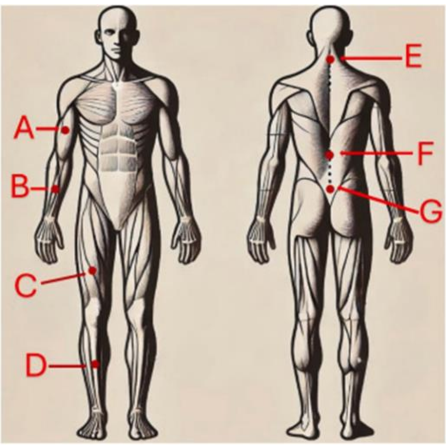


Figure 4. Sensor placement on the paramedic: front and back views.

Table 3. Summary of sensor locations.

Symbol	Sensor Placement on Body Model
A	Upper arm (right and left)
B	Forearm (right and left)
C	Thigh (right and left)
D	Lower leg / shank (right and left)
E	Pelvis
F	Lower back (lumbar spine)
G	Upper back (thoracic spine)

After positioning all sensors correctly, a calibration procedure was performed. During this stage, the participant was required to remain motionless in a defined stance—upright posture, feet aligned at hip width, and arms resting along the torso at shoulder width. This configuration was treated as the zero-angle reference, with negative values reflecting movement or tilt to the left, and positive readings indicating movement to the right. Once calibration was completed, the paramedic proceeded to carry out the designated procedures (P1–P5). All angular deviations recorded during the tasks were expressed relative to this zero baseline.

Evaluation criteria

Criteria for evaluating the individual joints were established using recognized normative values for the normal range of motion, provided in **Table 4**. Range of Motion (ROM) represents the extent to which a joint can move through its full functional arc. ROM may be measured under active or passive conditions. Although typical ranges exist for each joint, capabilities differ across individuals. Age-related decline and chronic musculoskeletal issues often reduce these ranges. ROM describes the total excursion achieved by a body segment and may be defined in linear or angular terms. The reference values correspond to adults aged 18–65, representing the working-age population. Two sets of ranges are listed because published values vary slightly across sources. The values represent averages for both sexes, despite the fact that women commonly have greater ROM in certain joints.

Table 4. Normal ranges of joint motion.

Joint/Segment	Plane of Motion	Direction of Motion	Standard ISOM Range (degrees)
Cervical Spine	Sagittal	Extension → Flexion	0° → 40° (0–0 – 40°)
	Frontal	Left lateral flexion → Right lateral flexion	0° → 45° (45–0 – 45°)
	Transverse	Left rotation → Right rotation	0° → 50° (50–0 – 50°)
Thoracic Spine*	Sagittal	Extension → Flexion	0° → 25–35° (25–0 – 35°)
	Frontal	Left lateral flexion → Right lateral flexion	0° → 25° (25–0 – 25°)
	Transverse	Left rotation → Right rotation	0° → 30° (30–0 – 30°)
Lumbar Spine*	Sagittal	Extension → Flexion	0° → 15–50° (15–0 – 50°)
	Frontal	Left lateral flexion → Right lateral flexion	0° → 20° (20–0 – 20°)
	Transverse	Left rotation → Right rotation	0° → 5° (5–0 – 5°)
Lumbo-thoracic Spine	Sagittal	Extension → Flexion	30° → 85° (total 30–0 – 85°; often 35–0 – 85°)[1]
	Frontal	Left lateral flexion → Right lateral flexion	0° → 30° (total 30–0 – 30°; often 45–0 – 45°)[1]
	Transverse	Left rotation → Right rotation	0° → 45° (total 45–0 – 45°; often 35–0 – 35°)[1]
Hip	Sagittal	Extension → Flexion	0–15° → 125° (15–0 – 125°)
	Frontal	Adduction → Abduction	0–25° → 45° (45–0 – 25°)
	Transverse	Internal rotation → External rotation	0–40° → 45° (45–0 – 40°)

Source: ISOM – International Standard for Orthopedic Measurement.
aROM values from references [21] and [22].

Recording muscle tone during medical tasks

Muscles tested

The study examined activity in 11 muscles. The assessed muscles are presented in **Table 5** and illustrated in **Figure 5**.

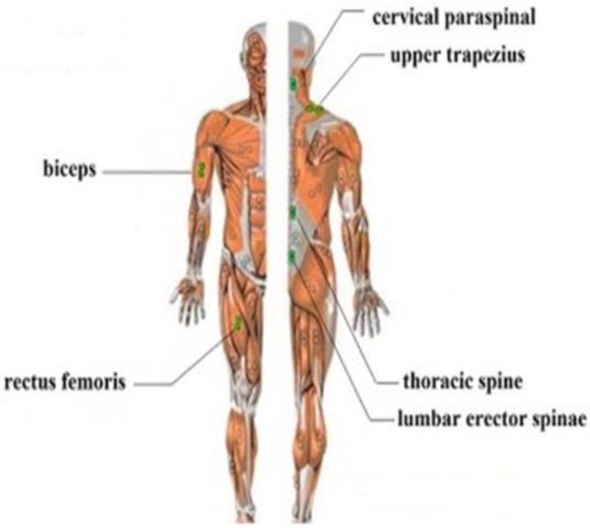


Figure 5. Muscles included in the analysis.

Table 5. List of monitored muscles.

No.	Muscle (full anatomical name)	Side
1	Cervical paraspinal muscles	Right
2	Cervical paraspinal muscles	Left
3	Upper trapezius	Right
4	Upper trapezius	Left
5	Biceps brachii	Right
6	Biceps brachii	Left
7	Thoracic erector spinae	Right
8	Thoracic erector spinae	Left
9	Lumbar erector spinae	Right
10	Lumbar erector spinae	Left
11	Rectus femoris	Left

Measuring equipment

Electromyographic activity was captured using a Noraxon system. Signal acquisition was supervised via a computer interface, with recordings made using Noraxon MR software version 3.10.64. The EMG sampling rate was 1500 Hz, and the device's frequency bandwidth ranged from 10 to 500 Hz.

Research procedure

Electrodes and sensors were applied following SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) guidelines. After placement, EMG readings were taken during a resting state ("relax: rel") and during active muscle contraction under standardized conditions ("ref"). The ratio of the reference signal to resting activity was used to verify recording quality and served as the basis for normalizing EMG data captured during the medical procedures. **Figure 6** shows sensor locations for the trapezius and cervical paraspinal muscles. Measurement duration matched the length of each procedure and was conducted while the ambulance was in transit.

Figure 6. Sensor placement for EMG recordings.

Parameters analyzed

The results were evaluated using both time-domain and frequency-domain EMG parameters. Key indicators included the root mean square (RMS) amplitude for signal magnitude and the mean power frequency (MPF), calculated via Fourier transformation. RMS amplitude is a widely used marker of muscle activation. It is computed as shown in formula (1), based on fixed-length segments ("windows") of the EMG signal.

$$\mathrm{RMS} = \sqrt{\frac{\sum_i^n x_i^2}{n}} \quad (1)$$

Where: n – the count of control points (window length); Xi – the i-th causal value [23].

Evaluation criteria

The indicators used to assess EMG activity derive from physiological mechanisms occurring in muscles exposed to static loading. When a muscle sustains a static effort, increasing force progressively restricts blood circulation. **Table 6** summarizes the permissible duration of muscle contraction relative to the percentage of maximal voluntary force. Muscle activation exceeding 20% of a muscle's maximal strength was treated as an indicator of abnormal static load, typically associated with constrained or awkward postures required during the evaluated tasks. The 20% cut-off for abnormal static load is supported by prior findings (ISO/TC 159/SC 3 WG 3 N 15), which connect values beyond this level with heightened fatigue and a greater likelihood of injury during prolonged static exertion.

Table 6. Maximum allowable time under muscle contractiona.

(as % of Maximum Voluntary Contraction – MVC)	Maximum Sustained Contraction Time Allowed (seconds)
Less than 5%	60
5–10%	30
10–20%	15
Greater than 20%	5

aISO/TC 159/SC 3 WG 3 N 15 Anthropometry and biomechanics.

Results and Discussion

Range of motion in spinal and hip segments during emergency medical procedures

The analysis includes 15 motion ranges covering the cervical, thoracic, lumbar, and hip regions. **Table 7** displays the measured values across 5 emergency procedures performed in an ambulance on an injured patient, together with the extent to which normal limits were surpassed for each task.

Table 7. Exceedances of normative motion ranges for each medical procedure.

	Exceedances from normal ranges of motion*				
	P1 immobilization of lower limb	**P2** immobilization of upper limb	**P3** thermal insulation	**P4** stopping of lower limb hemorrhage	**P5** trauma examination.
Cervical Spine					
Extension					
Flexion					
Cervical Lateral					
Left lateral bending					
Right lateral bending					
Cervical Axial					
Left rotation					
Right rotation		3.51		10.80	
Thoracic Spine					
Extension	0.98		16.09		
Flexion					16.11
Thoracic Lateral					
Left lateral bending	19.36				
Right lateral bending	2.55	9.11	**27.16**	10.35	7.08
Thoracic Axial					
Left rotation	9.79				
Right rotation		**24.17**	**29.78**	19.80	18.48
Lumbar Spine					
Extension					
Flexion	5.06	1.85	3.48	22.96	
Lumbar Lateral					
Left lateral bending	1.97	14.27	**20.17**		
Right lateral bending		1.45	**21.30**	**24.73**	**29.02**
Lumbar Axial					
Left rotation	6.39	**96.43**	**56.73**		9.61
Right rotation	11.47		5.20	**89.83**	**60.10**
Hip (Left)					
Extension	**61.63**		5.83		
Flexion					
Hip Lateral (Left)					
Abduction	9.64			**20.57**	
Adduction	5.23	8.30			
Hip Axial (Left)					
External rotation				**67.97**	**36.25**
Internal rotation	**64.76**	1.22			
Hip (Right)					
Extension	**50.51**	0.8			
Flexion					
Hip Lateral (Right)					
Abduction	9.46				
Adduction	**20.79**			**27.90**	
Hip Axial (Right)					
External rotation	**134.95**		**57.02**		
Internal rotation	**139.91**			**43.73**	5.63

* Green indicates acceptable exceedances, orange indicates acceptable, red indicates unacceptable

Adoption of constrained postures by paramedics arises from movement in specific spinal or hip segments. Exceedances greater than 20° were considered particularly meaningful, as smaller deviations may fall within individual variability and may not reflect genuinely forced postures. All analyzed procedures involved some degree of non-neutral position. Rotational motion, in particular, showed substantial overruns (approximately 56–96%) in the lumbar spine for all procedures except P1. Hip-joint motion also exceeded norms during P1 and P4. Procedure P1—lower-limb immobilization—generated the greatest loading on the hips, involving notable over-extension and rotational stress, with excessive external rotation in the left hip and internal rotation in the right hip. A favorable observation was that cervical spine deviations remained minimal across all tasks. Signal analysis included removal of measurement artifacts possibly caused by interference from ambulance equipment or sensor power loss during extended recordings.

Muscle tension during emergency medical interventions

The study demonstrated increased activation in several muscle groups. **Table 8** provides resting, peak, and mean RMS values for the monitored muscles, along with the percentage of muscle load relative to maximal RMS during the clinical procedures.

Table 8. Resting RMS, mean, maximum, and load expressed as a percentage of maximal RMS for each evaluated task.

Procedure	RMS	CERVICAL PS RT	CERVICAL PS LT	UPPER TRAP. RT	UPPER TRAP. LT	BICEPS BR. RT	BICEPS BR. LT	THORACIC ES RT	THORACIC ES LT	LUMBAR ES RT	LUMBAR ES LT	RECTUS FEM. LT
P1 Immobilization of the upper limb	RMS average	36.3	38.9	72.7	54.5	141	106	66.8	48.5	130	68	49.1
	RMS max	292	226	460	569	3410	2045	264	245	271	232	747
	RMS resting	9.96	13.1	14.6	25.6	2.37	4.72	17.9	5.87	10.4	20.4	28.8
	Average values as a percentage relative to the muscle's maximum RMS	12.4	17.2	15.8	9.6	4.1	5.2	25.3	19.8	48	29.3	6.6
P2 Immobilization of the lower limb	RMS average	28	29.4	46.8	42.7	88.4	98.3	47.9	37.2	92.2	53.8	26.8
	RMS max	292	226	460	569	3410	2045	264	245	271	232	747
	RMS resting	9.96	13.1	14.6	25.6	2.37	4.72	17.9	5.87	10.4	20.4	28.8
	Average values as a percentage relative to the muscle's maximum RMS	9.6	13	10.2	7.5	2.6	4.8	18.1	15.2	34	23.2	3.6
P3 Thermal insulation	RMS average	37.5	47.4	83.3	71.6	120	138	81.2	60.2	132	87.2	51.1
	RMS max	292	226	460	569	3410	2045	264	245	271	232	747
	RMS resting	9.96	13.1	14.6	25.6	2.37	4.72	17.9	5.87	10.4	20.4	28.8
	Average values as a percentage relative to the muscle's maximum RMS	12.8	21	18.1	12.6	3.5	6.7	30.8	24.6	48.7	37.6	6.8
P4 Stopping hemorrhage in the lower limb	RMS average	66.6	39	62.8	87.4	83.8	86.5	81.8	57.3	117	86.3	41.1
	RMS max	292	226	460	569	3410	2045	264	245	271	232	747
	RMS resting	9.96	13.1	14.6	25.6	2.37	4.72	17.9	5.87	10.4	20.4	28.8
	Average values as a percentage relative to the muscle's maximum RMS	22.8	17.3	13.7	15.4	2.5	4.2	31	23.4	43.2	37.2	5.5
P5 trauma examination	RMS average	50.9	36	73.1	64.4	179	85.2	64.5	66.1	112	104	42.8
	RMS max	292	226	460	569	3410	2045	264	245	271	232	747
	RMS resting	9.96	13.1	14.6	25.6	2.37	4.72	17.9	5.87	10.4	20.4	28.8
	Average values as a percentage relative to the muscle's maximum RMS	17.4	15.9	15.9	11.3	5.2	4.2	24.4	27	41.3	44.8	5.7

The findings indicated elevated muscle load in the thoracolumbar region, with the lowest activation occurring during upper-limb stabilization tasks. The multifidus muscle—right and left sides—showed the greatest tension across all procedures. Fatigue levels associated with increased muscle load depend heavily on both the length of time each posture must be held and the number of repetitions throughout a work shift. Some of the tension likely stems from the requirement to maintain postural stability; although the rectus femoris did not exhibit high activation, it still contributes to maintaining the necessary stance. All procedures were carried out by the paramedic in a standing posture.

Employee safety, regardless of profession, is governed by both national and international regulations. In recent years, organizations such as the European Agency for Safety and Health at Work (EU-OSHA), the International Labour Organization, and the World Health Organization (WHO) have emphasized the need to reduce work-related health concerns and emerging psychosocial threats. Findings published by EU-OSHA [24] further demonstrate that physical, organizational, and psychosocial conditions contribute significantly to occupational health issues. Work-related musculoskeletal disorders (WRMSD), now increasingly prevalent across nearly all industries, are particularly concerning due to their detrimental effects on worker health and the resulting financial impact on employers and society. According to European statistics, 60% of workers with job-related health problems identify WRMSD as their principal difficulty, with the most common complaints involving the back, neck, shoulders, and upper extremities. Reducing WRMSD risks requires a detailed evaluation of workplace conditions to determine which factors may provoke musculoskeletal strain. Numerous publications highlight these burdens and emphasize the urgency of implementing preventive measures [25].

In our investigation, we identified several burdens faced by paramedics, arising primarily from the adoption of unfavorable postures while performing emergency procedures. The analysis involved evaluating movement patterns of specific body regions and the muscle loads generated during standard interventions in an ambulance, both when stationary and in transit. The paramedic carried out these procedures on a medical simulator.

Our findings demonstrate that routine clinical tasks often push spinal and hip joint movements beyond typical physiological limits **(Table 7)**. Out of 31 analyzed angles, those tied to spinal and hip mobility were especially relevant. Across the studied procedures, normal motion thresholds were exceeded as a consequence of the constrained positions required to perform medical interventions. Deviations in the lumbar and thoracic regions were consistent, corroborating previous research [4, 14, 26–28]. Many of the examined tasks also demanded combined spinal movement and hip rotation, particularly evident in procedures P1, P3, and P4—lower-limb immobilization, thermal isolation, and control of bleeding from the lower extremity. Essentially, every intervention necessitated a non-neutral posture, and substantial rotational motion was consistently recorded. Such findings suggest a considerable risk of musculoskeletal complaints among personnel who regularly perform these activities.

Thus, it can reasonably be inferred that each procedure analyzed involved varying levels of discomfort due to exceeding several movement limits in the spine and hip joints. Elevated muscle loading in the lumbar area occurred during all procedures, with the smallest elevations noted during P2. The simultaneous occurrence of posture-related strain and increased muscle effort supports the likelihood of musculoskeletal problems.

Our results, combined with current literature, reinforce the crucial role of ergonomic factors in determining the safety of paramedics during medical procedures. These elements can considerably elevate the probability of occupational injuries. The degree of fatigue associated with heightened muscle tension **(Table 8)** is shaped by how long particular positions are held as well as how often procedures are repeated during a single shift. In 2022, emergency medical services in eastern Mazovia performed over 300,000 interventions, with 20% involving trauma cases. Additional strain arises from the requirement to maintain body stability while working on-site, inside a parked ambulance, or during patient transport. Such musculoskeletal loads may lead to long-term consequences such as degenerative spinal changes, ultimately prolonging sick leave [15, 16]. The results of this study indicate that these risk factors significantly contribute to the development of musculoskeletal disorders in paramedics.

Comparable challenges are documented in other EMS systems. In Germany, Eiche *et al*. [5] reported widespread musculoskeletal overload among paramedics, which contributed to increased turnover and reduced job satisfaction. Likewise, Friedenberg *et al*. [29] observed that resuscitation and patient-handling tasks often force workers into unfavorable postures, promoting overload. Many paramedics experience musculoskeletal injuries related to lifting and carrying patients or equipment [3, 6, 26, 30]. High injury rates among emergency personnel have been described in multiple national and international studies [2, 3, 31–33]. Musculoskeletal ailments remain a leading cause of work absenteeism [6, 34]. Daily work is often accompanied by pain, discomfort, and reduced well-being, stemming from prolonged static postures, manual handling of patients, and repeated awkward movements [4, 24, 35–38]. Maintaining uncomfortable positions for extended periods—even for many hours—can heighten pain, worsen mood, and increase vulnerability to injury [39]. Performing medical tasks in forced postures may lead to micro-trauma of the spine, contributing to chronic overload and degenerative progression [28].

Survey data from 120 paramedics employed in emergency departments in the Lublin region showed that 11.7% sought medical help due to back pain [14]. Another study from the Wielkopolska region investigated spinal pain occurrence during the previous 12 months in 70 paramedics aged 24–56 years working shifts. Most participants (62%) reported that pain appeared up to several times monthly, 17% experienced symptoms once per week, 13% several times per week, and 8% reported daily discomfort. Pain was predominantly located in the lumbosacral spine (64%), followed by the cervical (20%) and thoracic (16%) regions. Importantly, 94% had not experienced back pain before entering the profession. Respondents identified various contributors, including lifting (31%), maintaining constrained postures (23%), trunk flexion (16%), prolonged standing (9%) or sitting (6%), lifting loads (7%), twisting (5%), and excessive stretching (3%) [28].

Additionally, due to the nature of their tasks, paramedics face numerous hazards that may elevate the risk of accidents [40]. Studies consistently classify paramedics as a high-risk group exposed to severe injuries or fatal events. In Australia, this risk was reported to be six times greater than in the general workforce, while in the United States, mortality during emergency medical activities was more than twofold higher compared with other occupations [41].

Alson *et al*. [19] reported that tasks such as immobilizing limbs and managing bleeding are among the most physically taxing activities performed by paramedics. Our findings align with these observations, specifically showing elevated muscle engagement and joint loading during these procedures, underscoring the need for additional research aimed at improving ergonomic conditions in paramedic work.

Consequently, our results—demonstrating substantial musculoskeletal strain during routine ambulance procedures—correspond with the conclusions drawn in previous studies. Moreover, Friedenberg *et al*. [29] documented that 30 %–65 % of paramedics experienced back pain within the past year due to working in confined ambulance environments. Similar proportions were observed in our group of surveyed paramedics, indicating that this issue has a widespread, global character.

It is important to emphasize that our research covered 17 procedures, while the article presents analyses for five of them. These initial findings should serve as a basis for an in-depth assessment of paramedic working postures during each activity, including factors such as workflow organization, placement of equipment and medical supplies, and the internal layout of the ambulance. In addition, the duration and repetition of these postures should be examined. A comprehensive evaluation of these components will help identify the most demanding positions, reduce how often they occur, shorten the time spent in them, or replace them with safer alternatives, ultimately decreasing injury and accident rates among paramedics.

This pilot investigation identified forced postures during paramedic actions. The research was performed both while the ambulance was stationary and while it was moving, across 17 standard procedures, to determine which were the most ergonomically strenuous.

The article presents findings for 5 procedures that are most common when treating trauma patients, covering both joint range of motion and associated muscle tension. The study did not take into account anthropometric variation among paramedics. However, the workforce includes individuals ranging from the 5th to the 95th percentile, representing both genders.

Anthropometric dimensions may influence the ease and comfort of performing tasks, especially given that various tools and materials are placed in designated areas within the ambulance cabin. The presented results should therefore be treated as preliminary input for designing more ergonomic ambulance interiors and improving working comfort for paramedics, thereby lowering the risk of occupational injuries. The main limitation of this study is that only one participant was involved. Although the individual was highly experienced and performed typical tasks, using a single paramedic limits the generalizability of the results and does not capture differences in body size, experience, or ergonomic challenges faced by paramedics with varying physical characteristics.

To address this limitation, future work will include a larger pool of participants differing in age, sex, and anthropometric profiles. This will allow broader statistical analysis and provide deeper insight into variations in musculoskeletal demands associated with ambulance procedures.

Another limitation concerns the stretchers used in the study, which lacked height adjustment. Adjustable stretchers would likely decrease musculoskeletal strain by permitting more ergonomic working heights. Future studies should integrate height-adjustable stretchers to better determine how stretcher height influences musculoskeletal load and overall ergonomic outcomes.

Conclusion

The study identifies musculoskeletal overload arising from the forced body positions assumed during ambulance procedures. Therefore, it can be concluded that paramedics face a substantial risk of developing musculoskeletal disorders, a finding consistent with existing research in this profession. This work offers early evidence supporting the creation of methods to evaluate ambulance ergonomics. Such methodologies will make it possible to pinpoint sources of physical strain and support the design of ambulance interiors that enhance comfort, stability, and safety for emergency medical staff, thereby lowering injury risk during ambulance-based medical tasks. Although this pilot study provides essential initial observations, broader studies including more participants are planned. These will enable statistical analyses comparing musculoskeletal strain across different procedures and individuals, contributing to evidence-based guidelines for ambulance design and operational improvements.

The research identified several factors that impose forced, constrained postures during medical activities, including:

• External load created by the patient's limb weight.
• Poor placement of materials needed for procedures within ambulance storage areas.
• Absence of a suitable surface for organizing materials during tasks.
• Stretchers positioned too low (no height adjustment), forcing paramedics to bend over.
• Restricted access to the patient, often limited to one side or the head region.
• Inability to perform certain procedures while seated.

Minor interior adjustments can be made while ambulances are already in service. For instance, in the Meditrans Emergency Medical Services in Siedlce, safety nets were added to support paramedics performing activities in a standing position during vehicle movement. However, the optimal time to integrate such solutions is during the prototype stage, which is a focal point of our ongoing work.

Future investigations on a larger cohort—accounting for anthropometric diversity, gender differences, and additional medical procedures—will enable the development of recommendations for reorganizing ambulance cabin layouts. The overarching goal of this extended research is to achieve standardization in ambulances of the same type, thereby improving both efficiency and comfort in paramedic tasks.

Further studies should also evaluate psychological stress alongside physical workload. Understanding how stress influences performance and interacts with musculoskeletal strain may lead to more comprehensive strategies for enhancing both the physical and mental health of emergency medical workers.

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