



LINET spol. s r.o.
Želevčice 5
274 01 Slaný

SPECIALISED MEASUREMENT AND EVALUATION REPORT

Client: LINET spol. s r. o.
Date: 8. and 9. 4. 2021
Location: LINET spol. s r. o., Želevčice 5, 274 01 Slaný
Objective: Assessment of load on patients and personnel during use of Multicare and Multicare X therapeutic beds
Implemented by: Ing. Tomáš Lebeda, Mgr. Jaroslav Močigemba, Mgr. Eva Hrubcová

In response to to your order no. 4700017820 from 18. 3. 2021, measurements of local muscular load were conducted on 8 and 9. 4. 2021 using integrated electromyography, measurement of push/pull force and positioning to enable specialised assessment of physical load occurring during use of Multicare and Multicare X intensive care and therapy beds. For more detailed specification, assessment was made of changes in physical load on nurses when using the Lateral Tilt function for moving patients, and physical load on patients when subjected to the Mobi-Lift® function.

Method and measurement conditions, apparatus used and evaluation methodology

Measurements were conducted by the following methods:

A) Digital tensiometry

A digital tensiometer with FG 100 ID 34799 sensor unit and ID 157818 load cell, universal holder and extension pieces was used for measuring push/pull forces and forces exerted by manipulation with patients.

B) Integrated electromyography

Integrated electromyography was used to examine local muscular load. Integration is a mathematical process for calculating the area under a curve. A full-wave rectifier and electronic integrator are used for EMG signal integration. The integrated electromyogram shows total muscular activity and is a function of the amplitude, duration and frequency of the individual EMG potentials. A portable 8-channel polygraph was used for measurements and an EMG Holter with 4 EMG modules was used to record physiological parameters. EMG modules measure and record the electrical potentials that accompany muscular activity and serve to monitor muscle function. EMG potentials are recorded by special surface electrodes. The acquired signal is amplified by a differential amplifier, filtered (to suppress line noise at 50 Hz), full-wave rectified, integrated, digitalised and regularly cached. EMG signals are sampled at a rate of 20 times per second. The ensuing mean values are calculated and stored in the system's memory.



The sampling frequency for iEMG assessment is 1 Hz, which determines the mean value of force within a 1 second interval.

C) 3D Static Strength Prediction Program™

3D SSPP software predicts static strength requirements for tasks such as lifts, presses, pushes, and pulls and also evaluates task acting compression of intervertebral disc L4/L5.

D) Motion Capture

Motion Capture technology was used to record posture, using a Noitom motion capture suit; the applied method used 17 sensors with a sampling rate of 30 Hz.

Testing site and tested subjects:

Measurements were conducted at a LINET facility where the two therapy beds were installed. For improved variability and better information value of results, all activities were repeated by a minimum of three subjects out of a total of eight, who alternated. The set comprised four stand-ins, substituting hospital personnel (nurses) and a further five stand-ins substituting in-patients. The stand-ins for nurses were health professionals with requisite experience or knowledge of positioning patients. The stand-ins for patients were adult volunteers. Each activity was measured on several subjects in several repeating cycles, numbering 5–15.

Table 1: anthropometric data of stand-ins – nurses

Category	Sex	Height (cm)	Weight (kg)	Age (years)	Laterality of upper limbs
N1	Female	158	53	36	Right-handed
N2	Female	160	70	44	Right-handed
N3	Female	168	62	32	Right-handed
N4	Female	170	68	40	Right-handed

Table 2: anthropometric data of stand-ins – patients

Category	Sex	Height (cm)	Weight (kg)	Age (years)	Laterality of upper limbs
P1	Male	192	102	20	Left-handed
P2	Male	184	98	21	Left-handed
P3	Male	178	83	32	Left-handed
P4	Female	170	62	21	Right-handed
P5	Female	165	65	22	-



Measured objects:

Medical device – Multicare & Multicare X – intensive care and therapy beds intended as a solution for the demanding special needs of critically ill patients.

- Multicare's platform provides continuous lateral rotation therapy via the bed frame known as Automatic Lateral Therapy® (ALT). Simple programming allows patients to rotate up to 30 degrees for continuous therapy. This feature of Multicare supports ventilated patients and allows continuous individualised ventilation care.
- Manual 15-degree platform-based Lateral Tilt function is designed to assist nurses with turning patients. Tilting the bed with a foot pedal provides free hands for safe and effortless turning of the patient.
- To support patients while standing up the bed is equipped with a unique Mobi-Lift® solution. The Mobi-Lift® handle is designed to actively support patients' mobilisation. The handle serves as a stable point and can set the bed to an ideal height for standing to reduce physical strain on the patient.

Collaboration with measurements:

Results and evaluation of MotionCapture technology were provided by CIE s.r.o. who also took part in measurements. The report on position measurements is in annex 2.

Project objectives

(A) evaluation of physical load on hospital personnel positioning patients onto the side, using a bed with Lateral Tilt function.

(B) evaluation of physical load on patients when rising from a bed using Mobi-Lift® function.

The results of both sets of evaluations are compared to results acquired on beds without using either of the above functions.



Abbreviations:

MVC	maximum voluntary contraction
FL	left flexor muscle groups
FR	right flexor muscle groups
EL	left extensor muscle groups
ER	right extensor muscle groups



(A) Evaluation of physical load on nurses turning patients onto their side with and without use of the Lateral Tilt function

After the patient and nurse stand-ins were briefed, measurements were made for manipulation of patients under normal conditions by turning them onto their side without use of the Lateral Tilt function. Next, measurements were taken during use of Lateral Tilt. The two types of manipulation differed widely. During regular manipulation without use of the function the nurses moved the patient using their own strength only. Patients are held in the pelvic region and by the shoulders, and pulled onto their side towards the nurse. During manipulation with use of the Lateral Tilt function the nurses balanced the patient against the tilt by holding the pelvic region and shoulders more from the top. Turning a patient onto their side with Lateral Tilt is facilitated by a footswitch, and a suitable angle of tilt is determined by touch as the patient begins to turn on the slant of the bed.

Methods used:

iEMG:

- Upper limbs – placement
 - o Flexor palmaris longus of right arm
 - o Extensor digitorum of right arm
 - o Flexor palmaris longus of left arm
 - o Extensor digitorum of left arm

Motion Capture:

- Neck
- Upper limbs
- Trunk
- Lower limbs

3DSSP

- Compression of intervertebral disc L5/S1

A1) iEMG – Evaluation method:

Records of iEMG are used to determine highest mean values of forces (maximum muscular force) as presented in the Tables below. The annex contains original data. For evaluation of upper limb force the percentage values of force are applied to maximum voluntary contraction of hands and forearms (MVC) determined by a power grip on a grip dynamometer with upper arms positioned loosely alongside the body, with forearms flexed at 90° to upper arms and with wrists in a neutral position.

1 – without use of the Lateral Tilt function



2 – with use of the Lateral Tilt function



A1) iEMG – Results upper limbs



NATIONAL INSTITUTE OF PUBLIC HEALTH
National Reference Unit for Occupational Physiology and Psychophysiology
 Accredited laboratory according to Act. no. 258/2000 Coll., on the Protection
 of Public Health, as amended for authorisation sets I7, I8, I9, I10 a I11
 Šrobárova 49/48, 100 00 Praha 10, Phone: 267 081 111, Fax: 267 311 188
 IČ: 75010330 DIČ: CZ75010330

Table 3: Maximum muscular force exerted by four nurses and five patients when turning patients onto their side - upper limbs

			Nurses and muscle groups															
			Nurse 1				Nurse 2				Nurse 3				Nurse 4			
Patient	Task type	Values	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL
1	Normal	Absolute values (0..255)	65.20	31.70	68.70	58.00	144.55	30.35	191.58	74.28	73.11	10.91	118.98	18.04	-	-	-	-
		Force (%)	89	27	69	39	129	26	107	52	58	9	52	12	-	-	-	-
	Lateral tilt	Absolute values (0..255)	22.90	18.90	18.30	27.30	56.25	19.48	50.46	44.53	15.98	4.80	26.94	8.91	-	-	-	-
		Force (%)	31	16	18	18	50	17	28	31	13	4	12	6	-	-	-	-
2	Normal	Absolute values (0..255)	-	-	-	-	146.94	32.73	162.57	101.18	64.24	11.23	122.23	15.78	-	-	-	-
		Force (%)	-	-	-	-	131	28	91	71	51	9	54	11	-	-	-	-
	Lateral tilt	Absolute values (0..255)	-	-	-	-	54.86	22.46	40.94	45.85	19.71	4.54	22.80	8.70	-	-	-	-
		Force (%)	-	-	-	-	49	19	23	32	16	4	10	6	-	-	-	-
3	Normal	Absolute values (0..255)	87.30	43.40	73.30	102.40	-	-	-	-	-	-	-	-	-	-	-	-
		Force (%)	119	37	74	68	-	-	-	-	-	-	-	-	-	-	-	-
	Lateral tilt	Absolute values (0..255)	24.20	19.30	21.00	37.90	-	-	-	-	-	-	-	-	-	-	-	-
		Force (%)	33	16	21	25	-	-	-	-	-	-	-	-	-	-	-	-
4	Normal	Absolute values (0..255)	-	-	-	-	-	-	-	-	46.91	7.58	62.80	13.92	43.95	39.00	51.40	39.44
		Force (%)	-	-	-	-	-	-	-	-	37	6	28	9	22	21	29	17
	Lateral tilt	Absolute values (0..255)	-	-	-	-	-	-	-	-	22.49	7.04	44.30	9.48	18.95	18.45	15.70	14.75
		Force (%)	-	-	-	-	-	-	-	-	18	6	19	6	10	10	9	6
5	Normal	Absolute values (0..255)	-	-	-	-	89.10	31.87	149.74	62.15	-	-	-	-	-	-	-	-
		Force (%)	-	-	-	-	80	27	84	43	-	-	-	-	-	-	-	-
	Lateral tilt	Absolute values (0..255)	-	-	-	-	31.24	30.50	41.53	48.06	-	-	-	-	-	-	-	-
		Force (%)	-	-	-	-	28	26	23	33	-	-	-	-	-	-	-	-

Table 4: Mean muscular force exerted when moving patients from a supine position to side-lying position

	PATIENT 1															
	ABSOLUTE VALUES								PERCENTAGE							
	NO TILT				WITH TILT				NO TILT				WITH TILT			
	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL
NURSE 1 and 4	33.7	31.9	28.3	27.5	17.4	15.6	9.1	13.2	100%	51.6	48.9	32.2	48.0			
NURSE 2	31.5	45.6	28.9	40.7	8.8	33.6	8.1	23.8		27.9	73.7	28.0	58.5			
NURSE 3	26.0	32.1	24.2	52.0	11.7	22.5	11.6	31.9		45.0	70.1	47.9	61.3			
	PATIENT 2 and 3															
	ABSOLUTE VALUES								PERCENTAGE							
	NO TILT				WITH TILT				NO TILT				WITH TILT			
	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL
NURSE 1 and 4	39.1	29.5	40.7	27.4	15.9	17.7	15.7	17.4	100%	40.7	60.0	38.6	63.5			
NURSE 2	27.0	46.8	25.5	39.7	10.3	31.5	11.9	25.1		38.1	67.3	46.7	63.2			
NURSE 3	26.3	28.3	24.5	41.3	13.2	18.5	9.7	27.9		50.2	65.4	39.6	67.6			
	PATIENT 4 and 5															
	ABSOLUTE VALUES								PERCENTAGE							
	NO TILT				WITH TILT				NO TILT				WITH TILT			
	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL
NURSE 1 and 4	21.8	33.6	28.4	33.9	9.7	21.9	8.4	21.3	100%	44.5	65.2	29.6	62.8			
NURSE 2	29.8	33.8	27.6	48.7	9.3	25.1	10.0	31.0		31.2	74.3	36.2	63.7			
NURSE 3	31.3	36.1	31.7	35.7	21.6	29.2	20.0	25.6		69.0	80.9	63.1	71.7			



Table 4 expresses mean force values recorded over several cycles of one type of action. The first set of values reflect manipulation with a patient without lateral tilt of the bed and are taken as 100%. The second set of values are relative to the first. Differences in the results are due to varying muscular force, duration of action and time elapsed between each action.

Table 5: Mean values of maximum muscular force exerted when manipulating with patients from supine position to position onto their side – upper limbs

		Average values (N1..N5 AND P1...P5)			
Task type	Values	FR	ER	FL	EL
Normal	Force (%)	79.4	21.0	65.2	35.8
Lateral tilt	Force (%)	27.4	13.0	18.2	18.3

A1) iEMG – Interpretation – Upper limbs

Manipulation of patients from a supine position to position onto their side involves greater use of flexor muscle groups of the hands and forearms than the extensor muscle groups. The maximum muscular force measured for the hand and forearm flexor muscle groups during one action when turning a patient onto the side without use of the Lateral Tilt function was on average 65% to 79% MVC, and 18% to 27% MVC when using Lateral Tilt. In the extensor hand and forearm muscle groups the exerted maximum muscular force during one action without use of Lateral tilt was on average 21% to 35% MVC, and 13% to 18% MVC when using Lateral Tilt.

Note:

The value of maximum muscular force (% MVC) is relative to the maximum muscular force of the hands and forearms exerted by MVC. Manipulation of a patient from a supine position onto their side is more demanding for the flexor muscle groups than the extensor hand and forearm muscle groups; the action involves holding a patient and pulling them towards oneself using a rotational manoeuvre.



A2) Postures – Evaluation method

Manipulation of patients from a supine position onto their side with and without use of Lateral Tilt was assessed according to ISO 11226, where the more problematic positions are viewed as the most relevant and essential for evaluation. The maximum values for positions of the trunk and upper limbs were reached during the farthest possible grip on the patient at the start of rotation. This is why positions are evaluated for this part of the action.

A2) Postures – Results

Table 6: Mean maximum value of individual work positions during manipulation of patients from supine position onto their side in three nurses

Segment	Posture angles (°)					
	Nurse 2		Nurse 3		Nurse 4	
	Normal	Lateral tilt	Normal	Lateral tilt	Normal	Lateral tilt
Neck flexion	37	36	35	32	34	39
Trunk flexion	66	60	63	59	65	57
RUA Arms forward raise	109	95	118	95	113	96
LUA Arms forward raise	109	95	118	95	119	113

Table 7: Mean maximum value of individual work positions during manipulation of patients from supine position onto their side, the values are means of the recorded values from nurses 2, 3 and 4

Segment	Average posture angles (°)	
	Normal	Lateral tilt
Neck flexion	35	36
Trunk flexion	65	59
RUA Arms forward raise	113	95
LUA Arms forward raise	115	101

A2) Postures – Interpretation

Manipulation of a patient using Lateral Tilt function necessitated a smaller degree of forward bend than when not using the function. On average, forward bend decreased from 65° to 59°, whereas forward raise of the right arm decreased from 113° to 95° and 115° to 101° on the left.



A3) Compression of intervertebral disc L5/S1

Compression of the L5/S1 intervertebral disc was determined on the basis of the positions shown in the Tables above, and forces as shown below. It represents the greatest compression value occurring during the manipulation process. Data have been evaluated for a female with height 166 cm and weight 67 kg, representative of the mean values for the nurses involved.

A3) Compression – Results

Table 8: Mean maximum forces exerted during manipulation with a patient from supine position onto their side in three patients

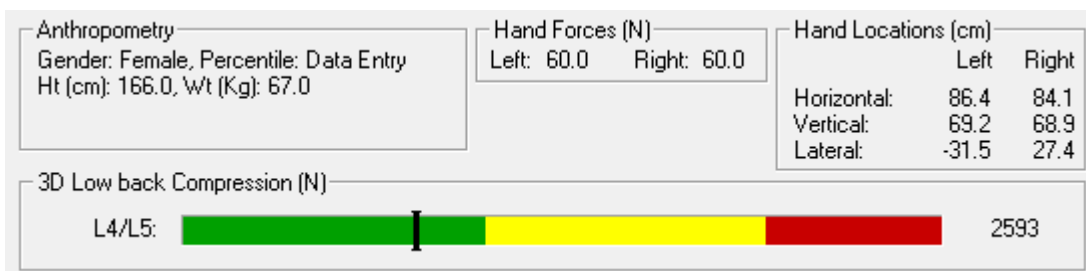
Maximum force (N)					
Patient 1		Patient 2		Patient 4	
Normal	Lateral tilt	Lateral tilt	Lateral tilt	Lateral tilt	Lateral tilt
140	43	141	39	82	36

Table 9: Mean maximum forces exerted during manipulation of a patient from supine position onto their side

Average maximum force (N)	
Patient 1, 2, 4	
Normal	Lateral tilt
121	40

Note.: Mean maximum forces measured as pull/push forces by digital tensiometry.

Compression of L5/S1 intervertebral disc during manipulation with an average patient without use of Lateral Tilt function



Compression of L5/S1 intervertebral disc during manipulation with average patient with use of Lateral Tilt function

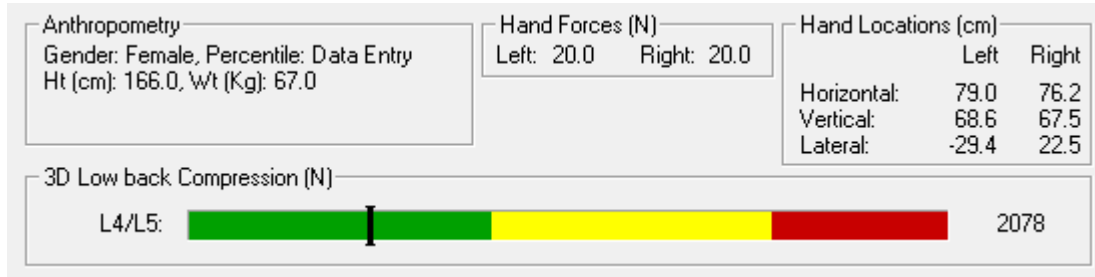


Table 10: Comparison of L5/S1 compression during manipulation of patient from supine position onto their side with and without use of Lateral Tilt function

	Compression L5/S1 (N)
Normal	2593
Lateral tilt	2078

A3) Compression – Interpretation of results

Manipulation of a patient from supine position onto their side without Lateral Tilt resulted in maximum L5/S1 compression of 2593 N against 2078 N with use of Lateral Tilt, a 20% decrease.



(B) Evaluation of physical load on patients during engagement of Mobi-Lift® function.

Prior to testing the patients were instructed in methods of rising from the different types of bed. Without use of Mobi-Lift® the hospital bed was situated at a height of 60 cm and patients were asked to rise in a normal manner with slight initial support of the hands against the mattress. During use of Mobi-Lift® the patients were at the starting height of 60 cm and were gradually elevated using the Mobi-Lift® handle to the maximum or other height where it was possible to naturally achieve a vertical position. During this action the patients held the operating handle in their right hand and the handle on the upper part of the bed in their left.

Methods used:

iEMG:

- Upper limbs – placement
 - o Flexor palmaris longus of right arm
 - o Extensor digitorum of right arm
 - o Flexor palmaris longus of left arm
 - o Extensor digitorum of left arm
- Trunk – placemenet
 - o Erector spinae left side
 - o Erector spinae right side
- Lower limbs
 - o Rectus femoris of right limb
 - o Rectus femoris of left limb

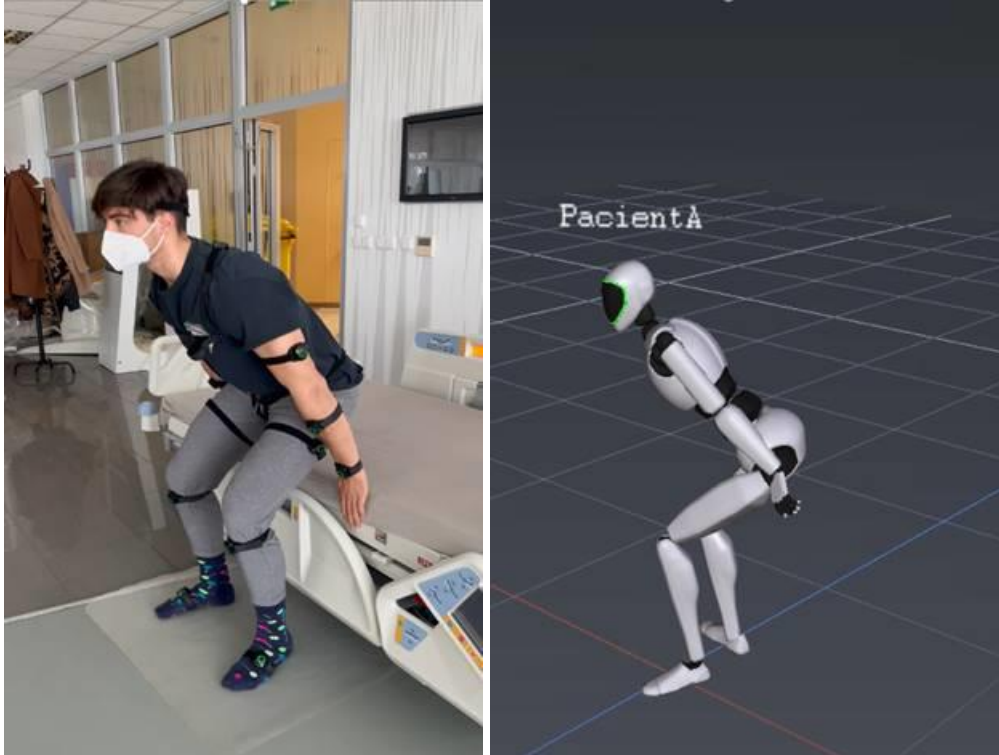
Motion Capture:

- Neck
- Upper limbs
- Trunk
- Lower limbs

B1) Evaluation method:

Mean maximum values (maximum muscular force) are calculated from iEMG records, as presented in the Tables below. The annex contains original data. For evaluation of upper limb force the percentage values of force are applied to maximum voluntary contraction of hands and forearms (MVC) determined by a power grip on a grip dynamometer with upper arms positioned loosely alongside the body, with forearms flexed at 90° to upper arms and with wrists in a neutral position. The trunk and lower limbs are evaluated by their mutual ratios where the force registered during rising from the 60 cm baseline is given as 100%.

1 – without use of the Mobi-Lift®



2 – with use of the Mobi-Lift®





B1a) Results – Upper limbs

Table 11: Maximum muscular force exerted when rising from bed in three patients – upper limbs

		Patients and muscle groups											
		P1				P2				P3			
Task type	Values	FR	ER	FL	EL	FR	ER	FL	EL	FR	ER	FL	EL
Normal	Absolute values (0..255)	99.75	18.40	56.00	11.30	7.40	5.50	2.40	1.40	79.96	11.71	61.92	22.71
	Force (%)	61	15	36	7	7	6	3	1	61	10	69	12
Mobi-Lift®	Absolute values (0..255)	10.50	7.63	5.25	65.00	49.70	2.80	3.50	1.70	17.71	6.93	8.64	24.93
	Force (%)	6	6	3	42	45	3	4	2	13	6	10	14

Table 12: Mean values of maximum muscular force exerted when rising from bed – trunk

		Average values (P1...P3)			
Task type	Values	FR	ER	FL	EL
Normal	Force (%)	43.0	10.2	36.0	7.0
Mobi-Lift®	Force (%)	21.8	5.0	5.8	19.2

B1a) Interpretation – Upper limbs

Rising from the bed results in mild engagement of upper limb muscle groups. When rising from the bed at a height of 60 cm the mean maximum muscular force of hand and forearm flexor muscle groups ranged between 36% and 43% of the maximum muscle force of hands and forearms inferred from MVC. The mean maximum muscular force of hand and forearm extensor muscle groups ranged between 7% and 10% MVC. When rising from the bed with use of Mobi-Lift® the mean maximum muscular force of hand and forearm flexor muscle groups ranged between 6% to 21% MVC, and between 5% and 19% MVC for extensor muscles.

Note:

Differences in recorded muscular force between the different modes of rising from bed are not great: the target population of patients with decreased mobility does not have upper limb condition as its primary limiting factor, and the results shown are of an informative character.

B1b) Results – Trunk

Table 13: Maximum muscular force exerted when rising from bed in three patients – trunk

		Patients and muscle groups					
		P1		P2		P3	
Task type	Values	EL	ER	EL	ER	EL	ER
Normal	Absolute values (0..255)	153.20	152.40	75.70	73.80	127.63	125.33
	Force (%)	100	100	100	100	100	100
Mobi-Lift®	Absolute values (0..255)	145.20	124.40	19.10	38.80	23.50	54.14
	Force (%)	95	82	25	53	18	43

Table 14: Mean values of maximum muscular force exerted when rising from bed – trunk

		Average values (P1...P3)	
Task type	Values	EL	ER
Normal	Force (%)	100	100
Mobi-Lift®	Force (%)	46.1	59.1

B1b) Interpretation – Trunk

Maximum muscular force exerted during rising from the bed with use of Mobi-Lift® ranged from 46% to 59% of force exerted when performing the same task without Mobi-Lift® function.

Note:

There were marked differences caused varying heights of the subjects. Even at the highest bed elevation the tallest patient had to compensate by slightly pushing off from the bed. This dynamic stabilising movement resulted in relatively high recorded force values which approached those found during rising from a bed at a height of 60 cm.

B1c) Results – Lower limbs

Table 15: Maximum muscular force exerted during rising from the bed in three patients – lower limbs

		Patients and muscle groups					
		P1		P2		P3	
Task type	Values	ER	EL	ER	EL	ER	EL
Normal	Absolute values (0..255)	64.00	74.67	85.90	56.10	49.17	59.58
	Force (%)	100	100	100	100	100	100
Mobi-Lift®	Absolute values (0..255)	24.00	16.13	6.88	20.38	36.29	26.00
	Force (%)	38	22	8	36	74	44



Table 16: Mean values of maximum muscular force exerted during rising from a bed – lower limbs

		Average values (P1...P3)	
Task type	Values	ER	EL
Normal	Force (%)	100	100
Mobi-Lift®	Force (%)	39.8	33.9

B1c) Interpretation – Lower limbs

Maximum muscular force exerted during rising from bed with use of Mobi-Lift® in lower limbs ranged from 33% to 39% in comparison to force measured without Mobi-Lift® function.

B2) Positions

Results are shown of patients rising from a bed with and without use of Mobi-Lift®. The comparison is targeted at evaluating the extent to which it was necessary for patients to rise in order to achieve a completely upright position whilst using Mobi-Lift® function. The baseline height of the top of the mattress during standing up without Mobi-Lift® was 60 cm, and this height designated as 100% sitting position. A 100% standing position was designated for each patient that stood upright with a mean 5° flexion of the knee joint.

B2) Positions – Results

Table 17: Percentages of the extent to which patients of varying heights must additionally rise whilst using Mobi-Lift®

		Patient 1 (Height 192 cm)	Patient 3 (Height 178 cm)	Patient 4 (Height 170 cm)
Mobi-Lift®	Stand	70%	100%	100%
	Sit	30%	0%	0%

The results show the endmost position to which patients rose to finish their mobilisation. A 192 cm tall patient using Mobi-Lift® achieved 70% standing position at 20° knee flexion. The other patients achieved 100% standing position with Mobi-Lift® function.

B1c) Positions – Interpretation

A male patient 178 cm tall and female patient 178 cm tall achieve 100% mobilisation from the bed using Mobi-Lift® function. A 192 cm tall patient achieves 70% standing position.



Concluding interpretation of results

Results from all measured parameters confirmed that the Lateral Tilt and Mobi-Lift® functions decrease load in patients and personnel. Decrease of load in personnel when moving patients onto the side with use of **Lateral Tilt** was confirmed by iEGM records of muscular force, showing **an average 69% decrease of maximum forces of flexor hand and forearm muscle groups** against regular manipulation without use of this function. Likewise, **L5/S1 intervertebral disc compression decreased by 20%** in the initial phase of manipulation. Improvements were also noted in working positions, forward bends and arms forward raise. Use of the Mobi-Lift® function decreased patient load when rising from a bed. Results clearly confirmed **100% standing position after elevation of patients up to 178 cm height**, whereas a standing position of 70% was achieved in the case of a 192 cm high subject. Use of **Mobi-Lift® function** led to decreased **lower limb load by an average 63%** and **decreased trunk load by an average 47%** against standing up in the normal manner. The results confirm that use of Mobi-Lift® function facilitate stand up for patients.

Note:

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Formulated by:

Ing. Tomáš Lebeda, Mgr. Jaroslav Močigemba, Mgr. Eva Hrubcová
NRU for Occupational Physiology and Psychophysiology

Approved by:

MUDr. Jana Hlávková
NRU for Occupational Physiology and Psychophysiology