

Quadriceps Muscle Activity, Weight-Loading and Patient Experiences during Two Different Pivot Transfers in Subacute Stroke Patients: A Randomised Controlled Pilot Study

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Abstract

Objective: Post-stroke patients must be early and frequent out-of-bed mobilised in order to improve recovery and prevent medical complications. However, evidence-based data for the optimal pivot transfer technique is missing. The objective of this study is to investigate whether there are differences in quadriceps muscle activity, weight-loading and patient experiences during two different pivot transfers in subacute stroke patients.

Methods: In a randomised controlled pilot study, six stroke patients (median age 56 (54-62) years, 8 (7-11) days post-stroke) participated. Each participant performed six pivot transfers (three each over the paretic and the non-paretic lower-extremity), assisted by a physiotherapist. Surface Electromyography, Pedar-X System and Patient Experiences Form measured the outcomes.

Results: The mean quadriceps muscle activity (peak) is for rectus femoris 165.39 (55.64) mV vs. 99.38 (55.64) mV, $p=0.35$; vastus lateralis 235.08 (72.96) mV vs. 174.13 (77.62) mV, $p=0.15$; vastus medialis 234.35 (86.92) mV vs. 605.80 (457.12) mV, $p=0.37$ comparing the paretic with the non-paretic lower-extremity. The mean weight-loading is 242.25 (89.08) Newton vs. 500.23 (71.05) Newton, $p=0.63$ comparing the paretic with non-paretic lower-extremity. The participants felt significantly safer (median score 1 (IQR 1-1) vs. median score 4 (IQR 4-4), $p<0.01$) and preferred pivot transfers over the non-paretic lower-extremity compare to the paretic lower-extremity (median score 1 (IQR 1-1) vs. median score 4 (IQR 4-4); $p<0.01$).

Conclusion: For the first time, we have evidence-based data for pivot transfers in subacute stroke patients. The results of quadriceps muscle activity and weight-loading indicate no statistically significant differences, while the participants are feeling significantly safer and prefer transfers over the non-paretic lower-extremity.

Keywords: Lower-extremity paresis; Mobilisation; Measurement; Patients experiences; Quadriceps muscle activity; Rehabilitation; Stroke; Surface electromyography; Weight loading

Introduction

Post-stroke patients must be early and frequent out-of-bed mobilised in order to improve recovery [1] and prevent medical complications [2-4].

In first-time stroke patients, the prevalence of motor deficit in the lower-extremity is estimated to 72% [5]. This deficit particularly affects independent physical activities such as transfer from bed to chair, sit-to-stand and walking [6,7].

Stroke patient's loose skeletal muscle mass [8]. The cerebral lesion cause loss of neural control and decreased sensorimotor adaption, leading to reduced stimulation of e.g. the lower extremity muscles.

Inactivity has also negative effect on skeletal muscle mass [9,10]. Bernhardt et al. reported that severe stroke patients were bed-ridden for more than 90% of the time during hospitalisation [11]. Report from Askim et al. indicated that stroke patients spent 30% of their time in bed, 46% sitting out of bed and 20% in higher motor activity [12]. In

healthy older adults 10 days of bed rest result in significant loss of skeletal muscle mass, especially in the lower-extremities [13]. Nozoe et al. reported that for non-ambulatory stroke survivors who were in acute inpatient rehabilitation, particularly during the period from admission to the second week, the quadriceps muscle thickness decreased in, not only in the paretic lower-extremity but also in the non-paretic one [14]. In addition, inactivity leads to decrease loading on bone mass increases [9] with the risk of falls and a hip fracture.

Furthermore, sarcopenia (age-related decline) is another element, which has a negative impact on skeletal muscle mass. Based on the Danish Stroke Registry ($n=78.617$) the mean age of women with stroke is 74 (SD 14) years and in men 65 (SD 12) years [15]. Because of this, it is important to exercise stroke patients to independent mobility e.g. throughout the optimal pivot transfer.

Any pivot transfer may promote muscle activity, prevent loss of bone mass and accelerate functional recovery for post stroke patients. However, performing pivot transfers in subacute stroke patients with a paretic lower-extremity needs to be safe [16] and without fear and risk of falls or injuries [16-18].

Pivot transfer is described as "a transfer of a patient from bed to chair with e.g. a physiotherapist (PT) standing in front of the patient,

encouraging them to lean forward and take their own weight through their feet. The PT then helps the patient to pivot 90 degrees to the chair” [19].

Two different pivot transfer techniques are used by clinicians, but their validity has been called into questions. Should we use: “the pivot transfer over the paretic lower-extremity” based on neurophysiological principles [20,21] or “the pivot transfer over the non-paretic lower-extremity” based on mixed motor relearning and task-specific principles? [22-25]. Hence, without evidence-based data, the optimal technique of pivot transfer in subacute stroke patients cannot be determined.

The objective of the present study was to investigate whether there are differences in quadriceps muscle activity, weight-loading and patient experiences during two different pivot transfers in subacute stroke patients.

Methods

Participants

Stroke patients admitted to the acute stroke units at Glostrup and Hvidovre University Hospitals were consecutive screened for inclusion according to the following inclusion and exclusion criteria.

Inclusion criteria: a) stroke, confirmed by computer tomography or magnetic resonance imaging scan; b) within 2 weeks post stroke; c) a paretic lower-extremity; d) medically and physically stable as by the doctors and the training physiotherapists at the departments; e) a score 3, 8 or 12 on the modified Barthel Index (subscale # 2. transfer, 0 -12) [26]; f) static and dynamic sitting balance; g) age >18 years and e) inpatient. **Exclusion criteria:** a) inability to give own name, time and place; b) inability to understand and follow instructions; c) inability to give informed consent; d) inability to speak Danish or English; e) paralysis of one or both lower- extremities; f) history of diseases which affect pivot transfer e.g. recent hip fracture, leg length discrepancy or foot complaints and f) other neurological diseases.

Design

In a randomised controlled pilot study the participants repeated two different pivot transfers, one over the paretic lower-extremity (A) and one over the non-paretic lower-extremity (B). Each participant performed a total of six pivot transfers, three of each.

The sequence of A and B pivot transfers were randomised using sealed non-transparent envelopes. A person with no relation to the study performed the randomisation.

All participants received verbal and written information and signed an informed consent prior to entering the study. The study was approved by the Ethical Committee of Copenhagen Capital Registration (H-D-2008-006) and registered in the Danish Register for Data Protection.

Measurements

Surface Electromyographic (sEMG)

The neuromuscular quadriceps muscle activity during the pivot transfers was quantified by sEMG (Wireless Transmission &

Datalogging system, Delsys Myomonitor[^] Wireless EMG System/ Myomonitor IV).

The sEMG reports the amplitudes of motor unit action potential responding to the force generated in the target muscle [27]. It has previously been used to measure muscle activity patterns during sit-to-stand transfers in stroke patients [28]. According to Roebroek et al. the quadriceps muscle is one of the main activators in the “seat off” movement in the pivot transfer [29]. Therefore, the sEMG signals were recorded from the three largest parts of the quadriceps muscle: m. rectus femoris (RF), m. vastus lateralis (VL) and m. vastus medialis (VM) on both the paretic and the non-paretic lower-extremity during each pivot transfer.

Procedure

Prior to the pivot transfer the procedure included following a) the skin was prepared for sEMG electrodes by shaving and cleaning with alcohol to reduce the electrode-skin impedance [30]; b) the sEMG electrodes were taped over the muscle bellies of the quadriceps muscle; c) the electrode location for RF was standardized at 50% of the distance from the anterior spina iliaca to the superior part of the patella. For VL at 2/3 of the distance between anterior spina iliaca and superior side of the lateral patella and for VM at 80% on the line between the anterior spina iliaca superior and the joint space in front of the anterior border of the medial ligament [31,32]; d) the data were recorded on the paretic and the non-paretic lower-extremity separately but in the same pivot transfer; e) each participant carried a small backpack or a belt to contain the equipment and f) as control of the muscle test the participants carried out three to five sets of maximum isometric contractions of the quadriceps muscle.

The pivot transfer: Each participant was instructed to perform six consecutive pivot transfers (three over the paretic and three over the non-paretic lower-extremity) with ≤ 1 min interval between each pivot transfer. The order of these transfers was randomised and each pivot transfer was performed from the participant’s own adjusted wheelchair to an examination bench, which was at the same level as the seat of the wheelchair. The bench was placed in the centre of a room at the Analysis Laboratory Hvidovre University Hospital.



Figure 1: Pivot transfer with no physical assistance.

Before each transfer, the participants were informed which side they had to transfer to. The instructions for pivot transfers were standardized as following “When I say start, lean forward, lift your buttock off the seat and move over to the bench”. The participants

moved without reaching a fully extended position. The sEMG data were controlled and manually recorded by the research leader (SLF) assisted by the staff at the Gait Analysis Laboratory. The research leader (SLF) took standardized readings on the sEMG and noted when pivot transfers were started and ended.

Physiotherapy assistance: A physiotherapist assisted the participants during each pivot transfer.



Figure 2: Pivot transfer with minimal physical assistance.

Initially it was planned that only two physiotherapists would be needed for the study, but one retired during the study, therefore a third

physiotherapist was recruited. Each of the physiotherapists had at least five years experiences in neurorehabilitation.



Figure 3: Pivot transfer with physical assistance and physical guidance for horizontal weight shift.

The physiotherapists were allowed to assist the participants verbally and physically. The degree of assistance during the pivot transfers was evaluated and documented by the PT at the end of each transfer. The evaluation was rated as a number on a 4-point ordinal scale (1=no physical assistance (Figure 1) 2=minimal physical assistance (Figure 2); 3=physical assistance and physical guidance for horizontal weight shift (Figure 3) and 4=maximum physical assistance (Figure 4).



Figure 4: Pivot transfer with maximum physical assistance.

Pedar-X system

The Pedar-X System (Novel Electronics Inc., St. Paul, MN, USA) measured the weight- loading on the feet at each pivot transfer. The

data were obtained through insoles [33] holding 99 capacity sensors in each telemetrically transmitting data to a computer via a central unit worn at the waist. The sensors monitor local loads from the sole interface at a frequency of 50 Hz.

The Pedar-X System has been reported as a repeatable in-shoe pressure tool [34] and test-retest reliability-assessing gait along linear incurred trajectories [35].

Procedure: In this study the participants wore their own, stiff shoes. Before pivot transfers the insoles were placed in the shoes. The Pedar-X System measuring was controlled and started by the research leader (xx) and the staff at the Gait Analysis Laboratory prior to participants executing the transfers. The instructions to the participants and the assisting PT are described in relation to the sEMG measure. The data obtained by sEMG and Pedar-X System were simultaneously. For pressure measurements the force-time integral (N*s) was calculated.

Patient experiences form

The participants evaluated their experiences [36,37] during the two different pivot transfer on the Patient Experiences Form. The Patient Experiences Form consists of eight questions grouped in relation to: muscle activity (first two questions), safety (next two questions), need for assistance (two questions) and preferred transfer side (last two questions).

Participants preformed their rating, by face-to-face interview, for each question on a 4-point ordinal scale, ranging from 1-4 (1=strongly disagree; 2=disagree; 3=agree, and 4=strongly agree) [38]. The Patient Experiences Form has not yet been tested for reliability or validity.

Data analysis

sEMG: In this study recorded signals were band-pass filtered from 10 Hz to 5 kHz. The mean (average amplitude) and peak were calculated for the RF, VL and VM in both the paretic and non-paretic lower-extremity during the two different pivot transfers.

Normalization methods: Maximum voluntary isometric contraction all sEMG values are calculated as a percent of that value: (sEMG activity+max sEMG activity)×100.

Statistical analysis

Statistical analyses were carried out using IBM SPSS (Statistical Package of Social Science) version 20. Data are presented as numbers (No), percent (%), mean and standard error of the mean (SEM) for larger samples and median and interquartile range (IQR) for small samples.

The null-hypothesis to determine the differences between the muscle activity and weight-loading was tested by Student's paired t-test. Within groups data on ordinal scale were analysed by Wilcoxon's signed rank test.

For all tests, the level for statistical significance was set to $p < 0.05$.

Results

Participants

In total, nine subacute stroke patients were included. Of these, three dropped-out (n=1, deterioration of medical condition; n=1, did not want to participate; n=1, did not complete all tests (due to technical problems), leaving six participants for statistical analysis. The sEMG at RF data from one participant were incomplete.

The demographic and neurological baseline characteristics of the six participants are presented in Table 1. The median time since last stroke was 8 (IQR 7-11) days and for Barthel Index (# transfer) 5 (IQR 3-8) points.

Characteristics	Participants (n=6) No (%)
Age, Years ^a	56 (54-62)
Gender	
Female	1 (16)
Male	5 (84)
Time since last stroke, days ^a	8 (7-11)
Subtypes of stroke	
Infarct	4 (67)
Haemorrhage	2 (33)
Localization	
Left hemisphere	1 (17)
Right hemisphere	5 (83)
Barthel Index	
(#2, transfer, 0-12 points) ^a	5 (3-8)
Hand dominance	
Left	0 (-)
Right	6 (100)

Table 1: The Demographic and Neurological Baseline Characteristics of Subacute Stroke Patients (^aMedium (interquartile range)).

The median neurorehabilitation experience of the assisting physiotherapists was 12 years (IQR 9-15). The median degree of physiotherapy assistance to the participants during the two different pivot transfers was 2 (IQR 2-3) over the paretic lower-extremity and 2 (IQR 2-2) over the non-paretic lower-extremity and without statistically significant difference ($p < 0.18$).

sEMG

The results of the quadriceps muscle sEMG (peak and mean) in the paretic lower- extremity during the two different pivot transfers are presented in Table 2. As seen in the table, the peak and mean values demonstrate no statistically significant differences.

The mean peak of RF and VL, but not of VM demonstrated higher values transferring over the paretic lower-extremity compare with the non-paretic lower-extremity (234.35 (SD 85.92) vs. 605.80 (SD 447.12)).

For pivot transfers over the non-paretic lower-extremity the quadriceps muscle sEMG (peak and mean) for RF, VL and VM were higher during pivot transfer over the non-paretic lower-extremity than over the paretic one. However, the results demonstrate no statistically significant differences (Table 2).

	Pivot transfer over paretic lower-extr.		Pivot transfer over non-paretic lower-extr.		p-value	
Quadriceps muscle	mV		mV			
	Peak ^a Mean ^a		Peak ^a Mean ^a		Peak Mean	
Paretic lower-extr.						
Rectus femoris ^b	165.39 (55.64)	36.95(14.8)	98.38(55.64)	30.08(13.29)	0.35	0.36
Vastus lateralis	235.08(72.96)	56.7(22.08)	174.13 (77.62)	59.68 (28.99)	0.15	0.73
Vastus medialis	234.35(85.92)	48.1(14.09)	605.8(457.12)	66.41(26.55)	0.37	0.35
Non-paretic lower-extr.						
Rectus femoris	224.93 (34.29)	63.20 (7.82)	262.60 (43.78)	79.61 (10.76)	0.14	0.19
Vastus lateralis	377.58 (46.02)	133.78 (22.82)	445.28 (73.22)	151.13 (17.80)	0.16	0.40
Vastus medialis	299.94 (39.82)	100.37 (17.62)	313.77 (47.06)	116.58 (18.78)	0.23	0.40

Table 2: Quadriceps muscle activity measured by surface EMG during two different pivot transfers in subacute stroke patients. sEMG: Surface electromyographic; mV: milli volt; Extr.: Extremity. ^aMean (Standard Error of the Mean). ^bData (n=5).

Pedar-X system

The results of weight-loading measured by the Pedar-X System in the paretic and non-paretic lower-extremity are presented in Table 3.

	Pivot transfer over paretic lower-extr. Peak-force, Newton Mean (SEM)	Pivot transfer over non-paretic lower-extr. Peak-force, Newton Mean (SEM)	p-value
Lower-extr.	Mean (SEM)	Mean (SEM)	
Paretic lower-extr.	242.25 (89.08)	500.25 (71.05)	0.63
Non-paretic lower-extr.	229.97 (75.38)	517.72 (61.03)	0.47

Table 3: Weight loading measured by Pedar-X System during two different pivot transfers in subacute stroke patients (Extr: Extremity; SEM: Standard Error of the Mean.).

There were no statistically significant differences between the results during the pivot transfer between the paretic and non-paretic lower-extremity.

The mean weight-loading in the paretic lower-extremity demonstrated a very small difference compare with the non-paretic lower-extremity (242.25 (SEM 89.08) Newton vs. 229.97 ((SEM 75.38) Newton.

Patients experiences form

The results of participants' experiences measured by the Patient Experiences Form are presented in Table 4. The participants felt significantly safer (p<0.01) and preferred (p<0.01) pivot transfers over the non-paretic lower-extremity compared with those over the paretic one.

There were consensus among the participants regarding safety transfer (over paretic leg median score 1 (IQR 1-1) vs. non paretic leg median score 4 (IQR 4-4) and preferred side (over paretic leg Median score 1 (IQR 1-1) vs. over non-paretic leg median score 4 (IQR 4-4).

Discussion

To our knowledge, the present pilot study is the first to investigate whether there are differences in quadriceps muscle activity, weight-loading and patient experiences during two different pivot transfers in subacute stroke patients. The results for quadriceps muscle activity and weight-loading indicate no statistically significant differences, while the participants' experiences indicate significantly greater safety and preference for transfers over the non-paretic lower-extremity.

sEMG

As expected, the quadriceps (RF, VL, VM) muscle activity is higher in the non-paretic lower-extremity compare with the paretic one. Unexpectedly, the quadriceps muscle activity in RF (peak and mean) is smaller than VL and VM, both in the paretic and non-paretic lower-extremity. This finding is similar to the result reported by Wen et al. studying thigh muscle function in stroke patients revealed by velocity

phase-contrast magnetic resonance imaging [34]. The difference was explained through the fact that RF is a biarticular muscle while VL and VM are monoarticular muscles [39]. It might also be the case that this smaller muscle activity in RF, also influences the so-called “stiff-knee-gait” pattern [40]. This gait is characterized by a decrease in swing phase by the paretic lower-extremity in stroke patients [41], but was not addressed in this study.

Question	Median (IQR)
1. Muscle activity	
1a. Did you feel muscle activity in the paretic leg during pivot transfer over the paretic leg?	3 (3-4)
1b. Did you feel muscle activity in the paretic leg during pivot transfer over the non-paretic leg?	4 (4-4)
p-value	0.1
2. Safety	
2a. Did you feel safe during pivot transfer over the paretic leg?	1 (1-1)
2b. Did you feel safe during pivot transfer over the non-paretic leg?	4 (4-4)
p-value	<0.01*
3. Need of assistance	
3a. Did you need more physiotherapy assistance when you performed pivot transfer over the paretic leg?	3 (2-4)
3b. Did you need more physiotherapy assistance when you performed pivot transfer over the non-paretic leg?	1 (1-4)
p-value	0,08
4. Prefer transfer side	
4a. Did you prefer pivot transfer over the paretic leg?	1 (1-1)
4b. Did you prefer pivot transfer over the non-paretic leg?	4 (4-4)
p-value	<0.01*

Table 4: Subacute stroke patient experiences during the two different pivot transfers measured by the Patient experiences form.

Pedar-X system

The results indicate weight-loading during pivot transfer to be more than twice as much over the non-paretic lower-extremity than the paretic lower-extremity. Crucial data in the analysis and decision-making before potentially gait relearning. Based on this issue Stoller et al. developed and evaluated a fast and easy-to-perform assessment for weight-bearing capacity in non-ambulatory subacute stroke patients [42]. Recently, Nadeau et al. reported that weight-bearing asymmetry was present in the first months (52.5 days) after stroke and persisted despite rehabilitation [43].

Patient experiences form

The participants indicated that they felt significantly safer and that they preferred transfers over the non-paretic lower-extremity to those over the paretic lower-extremity. These results are in line with Schmid et al. who reported that fear of falling was the most common reason for activity restriction in chronic stroke patients [16,18].

Investigation into patient experiences provides the healthcare professionals with important information regarding barriers and motivation, especially in patients with low resources such as subacute

stroke patients. Arnold et al. also investigated fear of falling during transfers, but in chronic stroke patients [44].

“Patient Experiences Form” is a key of knowledge and should be added as a measure in the rehabilitation of stroke patients.

Study Limitations

There are some limitations to this study. The first is the small sample size. The recruited participants were not representative of the subacute stroke population (sex, paretic side, deficits and their severity). However, in the study plan it was not intended to include a large number of participants due to inherent difficulties through factors such as transport to the Gait Analysis Laboratory at another hospital, and time duration for each test session.

The second difficulty concerned the lack of accurate recording by the sEMG and Pedar-X system. Due to the synchronous nature of these measurements, it was not possible to make accurate timing of the transfers. Therefore, the sEMG signal was diffuse from when a clear signal was visible to when it ended, which could include the mean sEMG signal since it is not certain that it reflects when the transfer really started and ended. Video recording could have been helpful

[45,46]. However, the participants had not received verbal and written information and signed an informed consent for video recording prior entering the study.

The final limitation was the lack of appropriate methods to measure the quadriceps muscle activity. The sEMG is the most commonly used method although it gives information only about the superficial part of the quadriceps muscle [47]. On the other hand, sEMG as an outcome measure can provide valuable data in the research of evidence-based rehabilitation of stroke patients.

Conclusion

For the first time, we have evidence-based data for pivot transfers in subacute stroke patients. The results indicate no statistically significant differences for quadriceps muscle activity and weight-loading, while the participants' experiences indicate significantly greater feeling of safety and preference for transfers over the non-paretic lower extremity.

Patient Experiences Form seems to be a key of knowledge and it is suggested to be added as a measure in the rehabilitation of stroke patients.

Larger studies using reliable and validated measurements are needed to investigate quadriceps muscle activity, weight-loading and patient experiences during different pivot transfers in subacute stroke patients.

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Conflicts of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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