The effect of complicated cases on the efficiency of musculoskeletal in-patient rehabilitation units in Hungarian healthcare systems

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Abstract

Efficient operation is increasingly important in healthcare systems as a consequence of the enormous amount of resources spent on healthcare services. The evaluation of the efficiency in this sector is particularly difficult, because of the aggregated character of efficiency. Data envelopment analysis (DEA) can handle this problem. The purpose of this paper is to apply DEA in order to measure the efficiency of rehabilitation units curing musculoskeletal disorders (diseases) in the field of in-patient rehabilitation care in Hungary. The examination focuses on the musculoskeletal rehabilitation units, where patients are treated following stroke or other acquired brain injuries. The novelty of the presented method is the consideration of the change of patients' functional status when efficiency is evaluated with DEA.

Keywords: Data Envelopment Analysis, healthcare, Efficiency, Rehabilitation

Introduction

Efficient operation is increasingly important in every production and service system. This is especially true in healthcare systems, which are responsible for an enormous part of government spending. For this reason, accurate and scientifically based efficiency results are needed to justify the proper use of financial resources.

Generally, different indicators are used for assessing the efficiency of a healthcare institution, like average length of stay (LOS), bed occupancy rate, mortality rate, number needed to treat (NNT) quality adjusted life year, etc. One of the major deficiency of these metrics is that they are independently measure the various characteristics of efficiency, and don't provide an overall characteristics of operation. Furthermore, the value of inputs and outputs are generally measured on different scales, consequently, comparison of the different elements of efficiency is difficult. To eliminate these shortcomings, generally scoring methods are used, which transform performance data into a common scale and an aggregate score is calculated with subjective weights.

Data envelopment analysis (DEA) is a special type of scoring method, which provides an objective method for aggregation. DEA is used to compare the performance of service systems using linear programming. The compared systems are called decision-making units (DMU). Several models and variables (inputs and outputs) are used depending on the field of application and on the healthcare resources. In the past decades, the application area of DEA has rapidly expanded (See for example Cooper et al., 2007; Emrouznejad et al.,2008; Spinks and Hollingsworth, 2009, 2008; Koltai et al., 2017). Use of the DEA model has become particularly popular in the healthcare (See for example Boussofiane et al. 1991; Kirigia et al., 2002; Akazili, et al., 2008; Lee, and Kim, 2012; Asandului et al., 2014). In one of our earlier research we have evaluated the performance of in-patient musculoskeletal rehabilitation units in Hungarian hospitals with output oriented slack based DEA models (Dénes et al., 2017). We have also applied the Barthel index for measuring (functional status) the health status of patients in a DEA model (Koltai et al., 2017).

In this paper, musculoskeletal rehabilitation units are examined, in the field of in-patient care in Hungary based on the data of a 2016 national survay. The objective of the presented research is to analyze how patient mix influences the efficiency at the units.

The novelty of the presented research is the consideration of the change of patients' functional status when efficiency is evaluated with DEA. The difference of patients' functional status before and after the rehabilitation program is an important indicator of the effectiveness of the service. Examination of the functional status is particularly important at the musculoskeletal rehabilitation units, where the operation is strongly influenced by the patients' functional ability.

In the following part of this paper, first the characteristics of patient-mix and the evaluation possibility of the health status of patients in the musculoskeletal rehabilitation are explained and the importance of the functional scales used in rehabilitation programs is discussed. Next, two DEA models are presented for efficiency analysis. The first model ignores the information of patients' health status and only concentrates on the number of patients treated. The second model considers health status information, and concentrates on the effectiveness of the treatment process. Next, the results of the two models and the effect of some health status related contextual variables are examined with correlation analysis. Finally, some important conclusions are drawn and further research possibilities are outlined.

Background of the research

This paper focuses on the performance evaluation of musculoskeletal rehabilitation in the in-patient units of Hungarian hospitals. These rehabilitation units show heterogeneous patient mix. The largest group is formed by those patients who suffer from different degenerative diseases (degenerative joint problems, spinal disorders, fibromyalgia etc.). In 2016 the ratio of these cases was 62 percent. The other main groups were formed by the stroke rehabilitation patients (14 percent) and post traumatic cases 8% (Dénes et al, 2017). Other functional problems that were treated at the musculoskeletal rehabilitation units are: diabetic foot complications, peripheral vascular disease, amputees, septic bone and joint problems, other neurological impairments, upper limb functional problems.

The patients, who suffer from different musculoskeletal diseases, require different rehabilitation programs. The rehabilitation of patients recovering after brain injuries, for example, after stroke, requires significantly more resources and more complex treatment, than the rehabilitation of patients with degenerative or inflammatory joint disease.

A stroke is caused by the interruption of the blood supply to the brain, leading to a necrosis (i.e. the cells that die) of the affected part. Stroke often involves functional degradation, for example upper/lower-limb paralysis, speech disorder, cognitive problems, and depression. Musculoskeletal rehabilitation activities and methods try to improve these abilities and skills. Life expectancies considerably decreases after stroke or brain injuries (Bonita, 1992; Warlow 1991), patients usually cannot move, walk, bath, eat, or dress without help.

In the following part of the paper after stroke and brain injured patients will be differentiated and will be mentioned as *SB patients*. Both the ratio and absolute number of the patients in this group will be used as an important characteristic of patient mix.

Several methods exist to measure the functional status of patients in the area of musculoskeletal rehabilitation. Generally, healthcare professionals evaluate the degree of independence of patients from outside help when performing several activities of daily living. The most common scales are the Barthel Index/Scale, the Functional Independence Measure, the Rivermead Scale, the International Classification of Functioning and the Modified Rankin Scale. The most well-known and widely used tool in practice is, however, the Barthel Index (Houlden et al., 2006). In Hungary, the use of Barthel Index became common in the 80's (Dénes, 2001). This index provides an aggregate measure of the basic abilities and life skills (mobility, dressing, transfer, feeding, climbing stairs, toilet use, grooming, bathing, bowel control, bladder control) needed to be independent. The maximum value of the Barthel Index is 100, which indicates that the patient is able to live without any help. In the following part of the paper, the Barthel Index is used to characterize the patient's functional ability and to evaluate the change of health status as a consequence of medical treatment.

The models of efficiency evaluation

A two stage DEA approach is used in this paper. First, two output oriented SBM DEA models are solved to get efficiency scores. More precisely, the first model ignores the health status information and only concentrates on the number of patients treated (quantity oriented model - Model 1). The second model considers health status information, and concentrates on the effectiveness of the treatment process (medical result oriented model - Model II).

The inputs of the two models are identical, and consist of the main resources used by the rehabilitation units. The inputs are the following: number of beds, number of physicians, number of nurses and number of therapists (special healthcare professionals). The outputs of the two models show the different objectives. The output of the first model is the number of treated patients. This model provides a quantity oriented efficiency measure which did not consider the effectiveness of the service. The output of the second model is the average change of health status of patients at the rehabilitation units. This model provides a service result based efficiency measure. In the second case, the initial health status of the patients and the rate of complicated cases within the patient population (SB patients) are also considered as non-discretionally outputs. The inputs and outputs of the two DEA models are summarized in Table 1.

The classic formulation of the output oriented slack based DEA models, found in Cooper et al (2007), is used, and the models are solved with the PIM-DEA software.

The applied data pertaining to all the 49 rehabilitation units operating in Hungary are taken form a country-wide data collection (Dénes et al, 2017).

In the second stage, correlation analysis is performed to analyze the relation of the efficiency results of the two DEA models and the effect of some environmental variables on the efficiency score. Considering some scaling problems of variables, the Spearman rank correlation coefficient is used.

Table 1 – Inputs and outputs of the two DEA models

	Model I	Model II
Objective	Quantity oriented model	Medical result oriented model
Inputs	number of beds	number of beds
	number of physicians	number of physicians
	number of nurses	number of nurses
	number of therapists	number of therapists
Outputs	number of patients discharged	the average change of Barthel Index (BI) of patients
Non-discretionary outputs	-	number of stroke and brain injured (SB) patients
	-	theoretical Barthel improvement possibility (entering 100-Barthel Index)

Evaluation of efficiency – Stage 1

Table 2 summarizes those rehabilitation units which were found efficient by both models. Column first shows, that unit C2, C14, C19 and C47 are found efficient by the quantity oriented and by the medical result oriented model as well. Based on the data in Table 2, it can be seen, that the SB ratio is low in these units. This means, that only a few patients have stroke or brain injury in these units. It can be assumed that these units gain their apparent efficiency from the less resource intensive rehabilitation tasks. SB patients require more work and resources compared to patients suffering from degenerative diseases. These units, however, are efficient by Model 2 (medical result oriented model) as well. Consequently, these units operate well and efficiently, thus improving the Barthel Index's value of the SB patients does not significantly reduce the number of patients discharged.

Table 3 contains the data of those rehabilitation units, which were found efficient only by the quantity oriented model (Model 1). Table 3 shows, that unit S7, S18 and S44 have very low SB ratio, and these units discharge relatively large number of patients. These data indicate that these units concentrate primarily on patients suffering from different degenerative illnesses.

Table 4 contains the data of those rehabilitation units, which were found efficient only by the medical result oriented model (Model II). Table 4 shows, that units C1, C3, C26, C29, C31, C36, C46 and C37 have a higher average SB ratio. C31 is a special unit with a significantly higher SB ratio (0,97), that is, almost all of the patients have stroke or brain injury. The C29 and C36 unit shows high average change of Barthel Index that could be the reason of their efficiency.

Table 5 summarizes the main characteristics of those units, which has high SB ration. It can be seen that units C31, C28, C29 and C37 operate with small number of beds. The Barthel Index at the admissions is relatively low and these units have the highest SB ratio. Thus the patients are at a lower self-sufficiency level, therefore they require more complicated and resource consuming rehabilitation treatment for recovering.

These units are found inefficient by the quantity oriented model (Model 1) but are found efficient by the medical result oriented model (Model II). In these cases, the difference in efficiency between the two models strongly indicates the importance of the application of the medical result oriented model, (that takes into account the change of patients' functional status).

Table 2 – Efficient rehabilitation units (DMUs) based on the two DEA models

DMU	Model 1 SBM Eff.	Model 2 SBM Eff.	No. of patients discharged	No. of SB patients	No. of rheumatism patients	Average change of BI	Barthel Index at admiss.	SB ratio
C2	100	100	975	22	910	26	44	0.211
C14	100	100	289	22	236	11	81	0.076
C19	100	100	762	116	495	20	60	0.152
C47	100	100	385	107	165	7	79	0.278

Table 3 – Efficient rehabilitation units (DMUs) based on (I. model)

DMU	Model 1 SBM Efficiency.	Model 2 SBM Efficiency	No. of patients discharged	Change of Barthel Index	Barthel Index at admissions	SB ratio
C7	100	54.2	767	8	83	0.057
C18	100	59.5	1453	15	65	0.070
C44	100	67.5	1386	23	54	0.156

Table 4 – Efficient rehabilitation units (DMUs) based on model (II. model)

DMU	Model 1 SBM Efficiency	Model 2 SBM Efficiency	No. of patients discharged	Change of Barthel Index	BI at admissions	SB ratio
C1	56.8	100	584	2	70	0,307
C3	34.2	100	355	7	68	0,211
C26	38.5	100	1016	10	85	0,342
C29	22.5	100	112	31	40	0,813
C31	23.8	100	214	18	62	0,977
C36	30.0	100	493	31	56	0,379
C37	27.7	100	375	7	52	0,464
C41	30.5	100	187	35	50	0,374
C46	39.3	100	1180	13	73	0,223

Table 5 – Efficiency of the rehabilitation units (DMUs) with hight SB ratio

DMU	Model 1 SBM Efficiency	Model 2 SBM Efficiency	SB ratio	No. of beds	No. of patients discharged	Barthel Index at admissions	Change of Barthel I.
C28	24.3	83.2	0.53	42	303	45	40
C29	22.5	100	0.81	20	112	40	31
C31	23.8	100	0.97	25	214	63	18
C37	27.7	100	0.46	30	375	52	7

Correlation analysis – Stage 2

The results of rank correlation analysis are summarized in Table 6. Note that the table contains only the Spearman rank correlation coefficients, however, the p-values (not listed here) confirm the conclusions listed below. Although, each correlation coefficient in the tables has interesting practical implication, only the most important results are explained in the following.

The rank correlation coefficient of the efficiency scores provided by the two models for the same DMU shows, that no any association can be assumed between the two efficiency scores (rho=0.345). This result indicates that a rehabilitation unit (DMU) which is inefficient according to the quantity based approach (Model 1) is not necessarily inefficient according to the medical result based approach (Model 2) as well. One would expect a negative correlation between the two efficiency score, but this is not justified by the analysis.

Table 6 – Spearman rank correlation coefficients

	μ_R	μ_R	SA	SA	Barthel	100–Barthel
	Model I	Model II	ratio	number	change	
μ_R – Model I		0.0345	-0.5009	-0.1277	-0.2974	-0.3244
μ_R – Model II			0.6923	0.4996	0.2668	0.4219
SA ratio				0.7357	0.2974	0.4318
SA number					0.2410	0.3620
Barthel change						0.6749
100–Barthel						

The analysis of the effect of the ratio of SB patients (ratio of stroke and other brain injured patients) on the efficiency scores shows the importance of the consideration of patient mix. The rank correlation coefficient shows, that SB ratio has a negative effect on the volume based efficiency score (rho=-0.5009). On the other hand, a strong positive association can be assumed between the medical result based efficiency score (Model 2) and the SB ratio (rho=0.6923). This result indicates, that SB ratio influences efficiency if efficiency calculation is based on Barthel improvement, and on the health status information of patients.

The analysis of the effect of the *number of SB* patients on the efficiency scores, however is not as straightforward as the effect of the *ratio of SB patients*. The rank correlation coefficient shows, that there is no any association between the number of stroke patients and the volume based efficiency scores (rho=-0.1277). On the other hand, a positive association can be assumed between the number of SB patients and the medical result based efficiency score (Model 2) (rho=0.4996).

This last result is explained by the fact, that the SB number is a no-discretionary output of Model 2. It is interesting to observe, however, that while the *number* of SB patients doesn't correlate with the efficiency scores of Model 1, the *ratio* of SB patients correlates with this efficiency score. The important is not the number of the complicated cases, but their ratio.

The analysis of the effect of the average change of Barthel Index shows, that a week negative association can be assumed between the volume based efficiency score (Model 1) and the average change of Barthel Index (rho=-0.2974). This result indicates that if effective medical service is provided, it has an adverse effect on quantity. The average change of Barthel Index is not an output of Model 1, but the more intensive use of resources in order to improve the health status of patients, if it is justified by their health status, influences quantity based efficiency.

The analysis of the effect of the average 100-Barthel value has also a week negative association with the volume based efficiency score (Model 1) (rho=-0.3244). This result shows that the health improvement possibility has effect on the quantity oriented evaluation. If there is possibility of improvement, then the more intensive use of resources to improve patient's health status has an adverse effect on the quantity based efficiency score.

Conclusions

The major question raised in this paper is, whether patient mix influences efficiency. A two stage DEA approach was applied to answer this question. First, DEA models were applied to calculate efficiency scores. Next, correlation analysis was used to analyze the effect of contextual variables on efficiency.

The first model (Model I) in this paper was quantity oriented. The calculation was based only on the major resources used by the rehabilitation units and on the patients attended. No any characteristics of the functional status of the patients were involved in the calculation. If, however, functional status influences the treatment process and the intensity of resource usage, then that must be reflected in the efficiency score. The analysis of correlation between the volume based efficiency core and the ratio or the number of stroke patients, did not show any evidence that patient mix influences efficiency scores.

In case of the second model (Model II), characteristics of the functional status of patients were involved in the calculation. In this case the ratio of SB patients has a positive correlation with efficiency, but the number of SB patients didn't influence the efficiency score.

We may conclude that if the DEA model does not use any special characteristics of patients, then the activity of the rehabilitation units can be considered homogenous, consequently, patient mix has no effect on efficiency.

The analysis also confirmed that better improvement of the health status of patients (higher average change of Barthel index) has an adverse effect on the quantity of patients attended. Consequently, a strictly quantity oriented performance evaluation does not serve the interest of patients.

Health status of patients in this paper was characterized by the Barthel index. This index has a long history in rehabilitation, it is methodologically well based, but its application contains several subjective elements. Furthermore, several other indicators exist in practice (eg. FIM) (Dénes, 2015). Consequently, it would be important to analyze the sensitivity of these results to the applied values of the Barthel index, or to the type of health status indicators applied. This is a topic of our future research.

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