Multivariate Associations between Health Outcomes and Health System Performance Indicators:
An Integrated Factor Analysis with Canonical Correlations

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OBJECTIVES

>The health outcomes of countries are dependent upon more than one variable, which is produced by a complex structural framework (1).

>Health system performance indicators such as the number of health human resources, number of beds, and health services capacity and volume of health services used to play a decisive role in the health outcomes of any society (2).

>Therefore, this study is designed to explore interrelationships between health system performance indicators and health outcome indicators.

>In this study, multivariate statistical analysis techniques were used to determine the relationships between multidimensional health system performance indicators.

METHODS

>A combinative strategy of explanatory factor analysis and the canonical correlation coefficient is used to define linear structural relations between study variables.

>Province-based data set was obtained from the official statistics of the Ministry of Health (MoH) and Turkish Statistical Institute (TUIK) for 2019 (3,4).

> Life expectancy at birth, infant mortality rate, and crude death rate were accepted as health outcome indicators and all other variables are presented in Table 1.

Table 1. Study Variables

Variable Group	Variable definition	Variable labels
Health Outcome Indicators	Life expectancy at birth	life_exp
	Infant mortality rate (‰)	inf_mortality
	Crude death rate (‰)	death_rate
Health System Performance Indicators	Number of total physicians per 100.000 population	physician
	Number of total dentists per 100.000 population	dentist
	Number of total pharmacists per 100.000 population	pharmacist
	Number of total nurses and midwife per 100.000 population	nurse_and_midwife
	Number of hospital beds per 100.000 population	hospital_bed
	Number of intensive care unit beds per 100.000 population	int_care_bed
	Per capita dentist visits	dent_visits
	Bed occupancy rate (%)	bed_occupancy
	Bed turnover rate	bed_turnover

Methodology Steps

1 First descriptive statistics such as median, minimum, and maximum values and Spearman rank correlations were used to explore baseline characteristics of study variables.

2 Secondly, Explanatory Factor Analysis (EFA) is performed to explore the latent structure of health system performance indicators (5).

3 Finally, a multivariate statistical analysis method called canonical correlation analysis (CCA) was used to examine the interrelationship between the indicators representing health outcomes and health system performance indicators (6).

RESULTS

> Baseline characteristics of health system performance indicators obtained from 81 provinces of Turkey are presented in Table 2. Minimum, maximum, and median values are presented due to the not-normal distribution of study variables.

> Varimax Rotated Principal Components Analysis is performed, and factors loadings are presented in Table 3.

>EFA results defined two variable sets which are named: (i) health human resources & health services capacity indicators, and (ii) health services utilization.

Table 2. Baseline characteristics of health system performance indicators

Variable	Median (min; max)
life_exp	78.1 (76.1; 80,7)
inf_mortality	8.5 (3; 16.2)
death_rate	6.1 (2.4; 9.9)
physician	156.93 (104.25;310.78)
dentist	30.53 (10.44;58.21)
pharmacist	38.23 (17.44;54.86)
nurse_and_midwife	318.18 (173.33;500.55)
hospital_bed	264 (119;506)
int_care_bed	40 (13;97)
dent_visits	0.69 (0.39; 1.39)
bed_occupancy	66.2 (42.3; 88.7)
bed_turnover	57.9 (35.9; 97.5)

Table 3. Explanatory factor analysis to define variable sets in independent variables

| Factors and items	Ranking of factor loadings	Factor loadings
Health human resources & health services capacity (Cronbach's alpha=0.76)		
hospital_bed	1	0.877
nurse_and_midwife	2	0.877
physician	3	0.865
dentist	4	0.842
dent_visits	5	0.698
pharmacist	6	0.657
int_care_bed	7	0.596
Health services utilization (Cronbach's alpha=0.63)		
bed_occupancy	1	0.881
bed_turnover	2	0.772
Kaiser Mayer Olkin (0.70) Bartlett's test of sphericity (X^2=491.833, p<0.01)		

Canonical Correlation Analysis Results

>Based on the two-factor structure obtained in the independent variables sets, a canonical correlation analysis was performed to identify the interrelationships between two independent variable sets and health outcome indicators.

>The Shapiro-Wilks (SW) multivariate normality test indicates multivariate normality for the set of health outcome indicators (group of dependent variables) (W=0.97, p>0.05).

>In this study, Spearman correlation coefficients (r_s) were used to explore similarities between study variables in three groups. Figure 1 presents a correlogram of independent variable groups. All correlations are under 0.80 and this figure shows the histograms and scatter plots between independent study variables, simultaneously.
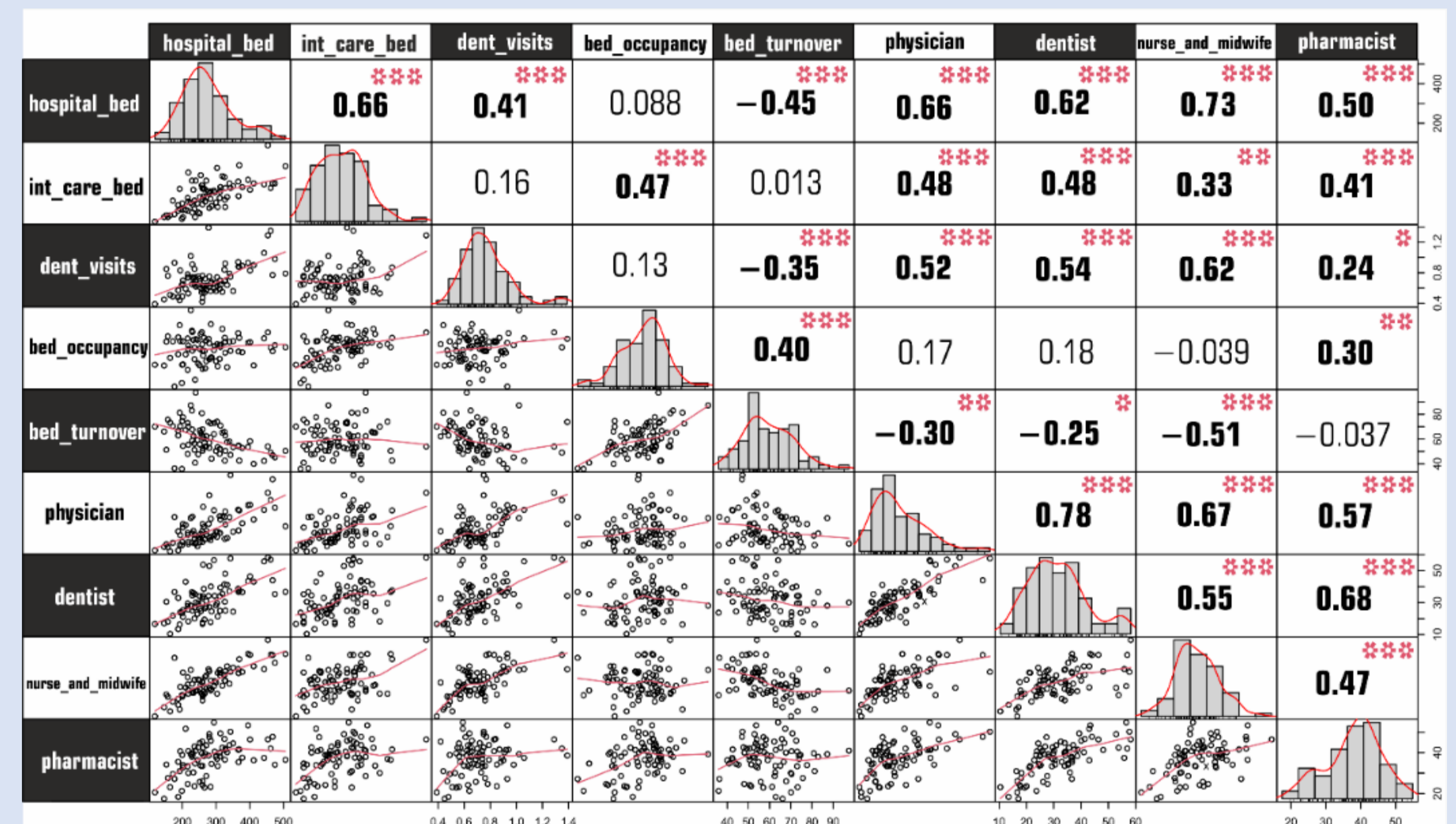
*** Correlation is significant at the 0.01 level, ** Correlation is significant at the 0.05 level

Fig. 1. Correlogram of independent variable groups

>Table 4 presents performance scores of canonical correlations and indicates the statistical significance of the two canonical correlation coefficients (p<0.001). The first canonical correlation obtained from a set of health human resources & health service capacity indicators and health outcome indicators indicates a strong interrelationship (r_{c1}=0.83). For the first and second sets of canonical roots, Figure 2A shows canonical score plots. There is a high statistical significance to the first set of roots regarding understanding the relationship between health human resources & capacity and health outcomes.

Table 4. Health human resources and health services capacity & health outcome indicators canonical correlation results

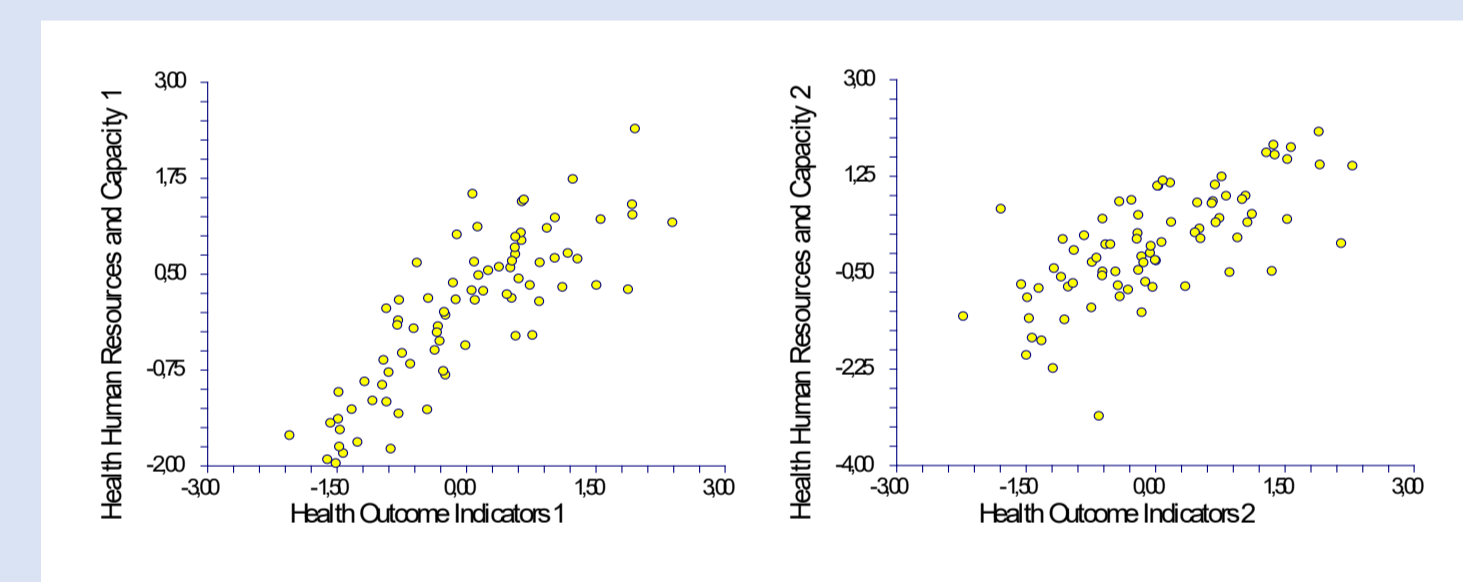|	Canonical Correlation	R-Squared	DF	Probability	Wilk's Lambda (λ)
1	0.83	0.69	28	0.000	0.12
2	0.69	0.48	18	0.000	0.39

Fig. 2A. Canonical Scores Plots

>Table 5 presents performance scores of canonical correlations and indicates the statistical significance of the two canonical correlation coefficients (p<0.001). The first canonical correlation obtained from a set of health services utilization indicators and health outcome indicators indicates a moderate interrelationship (r_{c1}=0.59). For the first and second sets of canonical roots, Figure 2B shows canonical score plots. There is a high statistical significance to the first set of roots regarding understanding the relationship between healthcare utilization and health outcomes.

Table 5. Health services utilization & health outcome indicators canonical correlation results

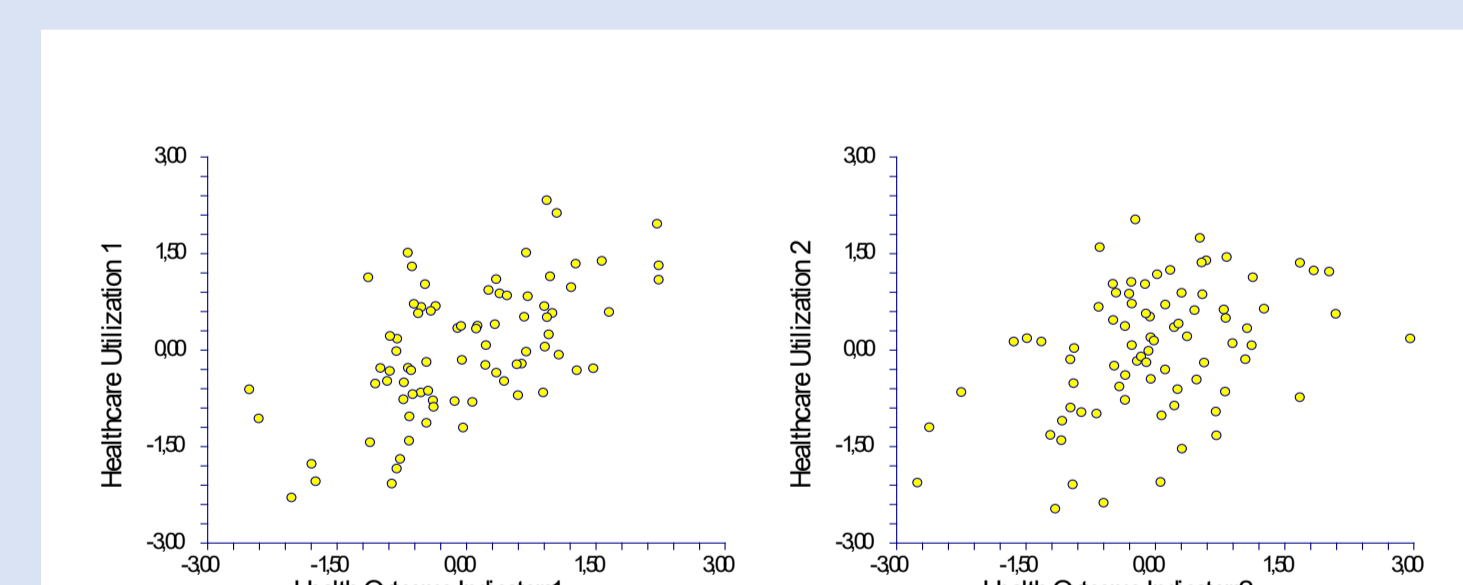|	Canonical Correlation	R-Squared	DF	Probability	Wilk's Lambda (λ)
1	0.59	0.34	8	0.000	0.54
2	0.41	0.19	3	0.003	0.83

Fig. 2B. Canonical Scores Plots

CONCLUSIONS

>In this study, we reveal the relationship between health outcomes and health system performance indicators. EFA showed that health systems performance indicators are in two groups: (i) health human resources & health services capacity and (ii) healthcare utilization. There exist strong positive correlations between health outcomes and health human resources & health services capacity indicators (r_c= 0.83) and health services utilization indicators (r_c=0.59), respectively.

>Multivariate statistical methods give robust and reliable results in determining the interrelationship between health system performance variables and health outcomes. Consequently, multivariate statistical techniques will be able to provide comprehensive information about health-related traits.

> Empirical findings, especially presented using indicators of a developing country, will lead the policies that they will create in a broad perspective for the states to raise the health system performance indicators with which health outcomes are interrelated with health system performance indicators. Moreover, we believe that this study will guide policymakers in addition to providing suggestions for future studies.

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