

Research Article

# Benchmarking Health Infrastructure in Türkiye and Other OECD Countries: Health Workforce, Medical Technology and R&D Activities in Health

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## Abstract

*As it has been seen during the COVID-19 pandemic period, medical technologies as well as the health personnel, especially the physicians (medical doctors) and nurses in health care resources played a crucial role in the early diagnosis and in the prevention of the disease. Advances in medical technologies allow the physicians and nurses to devote more time to patients and to deal with them in more detail.*

*In OECD countries, total health and social employment was 67.2 million and 20% of them, which was 13.45 million, were practising nurses, 6.3% of them, which was 4.2 million, were practising physicians in 2021. According to the WHO, total global nursing health workforce is 28.9 million, whereas total physicians are 12.8 million in 2020.*

*There were 36.7 “mammographs”, 7.6 “radiation therapy equipment”, 19.1 “gamma cameras”, 3.4 “positron emission tomography (PET) scanners, 35.7 “computed tomography (CT) scanners”, 25.1 “magnetic resonance imaging (MRI) units” per million population in OECD in 2021.*

*Gross domestic expenditure share on research and development (R&D) in medical and health sciences in GDP was 0.56% and the share of patent publications in medical technology in total patent applications was 6.2% in OECD in 2021.*

*Health expenditure per capita was 5,597dolar and health expenditure as a share of GDP was 13.2% in OECD in 2021.*

*It seems that health expenditure and human resources are not at the same level in every country. In addition, foreign trade of technological medical devices used in the diagnosis of disease is not distributed equally, since the purchasing power due to economic growth is not the same and sufficient resources are not allocated for R&D expenditures.*

*This study aims to investigate to benchmark the health infrastructure in Türkiye and other OECD countries considering the health workforce, medical technology and R&D activities in health.*

**Keywords:** Health workforce, medical technology, R&D in health, patents in health, foreign trade in medical technology

## 1. Introduction

The new type of coronavirus, which emerged in the last days of 2019 in Wuhan, China, spread rapidly all over the world, and the World Health Organization (WHO) declared the epidemic as a pandemic on March 11, 2020 (Gürler & Özsoy, 2020).

COVID-19 has adversely affected not only global supply chains and value chains, but also social life and economies in most of the countries. Many governments and international organizations have put decisions in action to reduce the negative impact of the pandemic, and have tried to support fragile economies, companies and individuals in collaboration, as well as taking strict protective decisions (Gürler and Özsoy, 2021).

Many countries have increased R&D in health to fight with the pandemic. While the pandemic negatively affected social and economic life, it also disrupted people's well-being and mental health (Demirbaş and Bozkurt, 2020).

Before pandemic, the WHO estimated that, there was a shortage of 18 million healthcare workers, mostly in low- and lower-middle-income jurisdictions by 2030 and nine million of them are the nurses and midwives (WHO 2016, WHO 2022a). Healthcare workers are healthcare's most valuable asset, but the industry's most valuable resource faces a number of challenges. COVID-19 has exacerbated these challenges by claiming and infecting the lives of healthcare workers, affecting their health and demanding rapid change in the way they work (KPMG 2022a).

During the COVID-19 pandemic period, it has been seen how important the health system especially the health personnel in the countries. Having a strong health workforce, especially medical doctors and nurses, made the countries more resistant against the pandemic. Nurses and medical doctors are the other main inputs of the health system in the countries. There was unequal access to health personnel and medical technology, and this problem has increased with the pandemic. In addition to the limited capacity of the health system in countries, low health expenditures, including R&D investments for medical technology and qualified health personnel, became major problems in the fight against the pandemic (Özsoy 2021). Health expenditure per capita and economic growth hence GDP per capita are positively correlated with each other (Özsoy and Gürler 2020).

The healthcare industry workforce is the majority of the professional jobs. In 2021, one of the ten jobs (10.7%) in OECD countries is in health and social care sectors, and it makes the sector among the largest employers. According to the latest OECD estimates, health sector jobs are therefore among the least likely to be automated, along with the

education sector, compared to the entire labour market. The developments in medical technology are in the direction of increasing the productivity of the workforce rather than reducing the workforce in the health sector (OECD 2019), although Schumpeter (1942) stated that technological developments (innovation) both increases the productivity and causes creative destruction as a result of industrial mutation. In the healthcare industry, demand for labour is expected to continue to rise as technology expands and supports new ways of working, role redesign, and new service delivery models (KPMG 2022b).

It seems that the COVID-19 pandemic is no longer an individual problem of a country; even for human development, it is a global issue and a cooperative partnership is needed. While the Global Human Development Index value was 0.739 in 2019, it was predicted to be 0.744 in 2020 and 0.749 in 2021 when the pandemic was not taken into account, while the index value decreased to 0.735 in 2020 and 0.732 in 2021 with the pandemic (UNDP 2022). The inadequacy of the health system to fight the pandemic and the negative impact of COVID-19 on working life and economic growth, as well as increasing poverty, have deteriorated the WHO SDGs of zero hunger, reducing poverty, good health and well-being and reducing inequality. (Özsoy and Gürler, 2022; UNDP 2022).

Approximately 1.2 billion people, half of whom are children, in 111 developing countries face multidimensional poverty. In addition, it is seen that the multidimensional index value still does not reach pre-pandemic values even in 2021 (UNDP and Oxford Poverty and Human Development Initiative "OPHI" 2022).

WEF (2017) classifies the countries into three groups such as factor (input), efficiency and innovation driven countries. The innovation-driven countries are the countries, which have R&D, patents and innovation to achieve production process and have more sophisticated products to trade in international markets.

Countries are investing in medical technologies to protect the health of their citizens and to diagnose the illnesses early. Countries that cannot afford to make such R&D investments and want to access medical technologies, which were produced by other countries, can meet their demands through foreign trade. Foreign trade in medical technologies helps countries to close the gap in medical technology production to some extent.

Innovation and patents are the core determinants of long-run economic growth. Invention, innovation and patents are related topics so that a patent has an exclusive right granted to an invention, which may be either a product or process. In the patent application, it is obligatory to disclose the technical information about the invention to the public (WIPO, 2022). Patent grants in medical technologies are output of innovative activities of researchers and R&D expenditures. Entrepreneurial universities should lead

the private sector to create technology at the beginning and they can cooperate to make innovation (Gürler 2021).

In a healthy and peaceful environment, both people and enterprises will live for a long time. Such an environment will improve the economy, so that its contribution to economic growth will be positive and the growth will have an increasing effect on income per capita. An economic growth that is not supported by innovation will not be permanent. If the production model based on cheap labour, resources and capital accumulation is not supported by innovation, as in the law of diminishing returns specified by neo-classical thought, marginal production will decline (Gürler 2016). Advances in the health care system, along with advances in innovation, will reduce mortality in a country and increase productivity and economic growth in a country, encouraging a long-living population with a higher life expectancy at birth and a healthy workforce (Gürler and Özsoy 2019). Global demand for innovative medical technology solutions continues to grow to have longer and healthier lives (GTAI 2019).

This study aims to investigate to benchmark the health infrastructure in Türkiye and other OECD countries considering the health workforce, medical technology and R&D activities in health for 38 OECD countries for 2010-2021 period.

## 2. Materials and Methods

This study will analyse the health infrastructure such as the health workforce, health expenditure, medical technology, R&D and patent activities in health sector and foreign trade in medical technologies for 38 OECD countries for 2010-2021 period.

### 2.1. Country selection

In the study, data for fifteen indicators, which are related with health, R&D, patents and foreign trade can be found for 38 OECD members. There was a lack of data for the indicators listed above for some countries for some years so the recent data were used for missing data.

The country set is analysed considering the indicators.

- Health expenditure per capita (\$): data from OECD (2022a) for 2010-2021 period [A],
- The share of health and social personnel in total employment (%): data from OECD (2022a) and WHO (2022) for 2010-2021 period [B],
- The share of practising nurses in total health and social personnel (%): data from OECD (2022a) and WHO (2022) for 2010-2021 period [C],
- The share of practising physicians in total health and social personnel (%): data from OECD (2022a) and WHO (2022) for 2010-2021 period [D],

- Health expenditure as a share of GDP (%): data from OECD (2022a) for 2010-2021 period [E],
- Gross domestic expenditure share on R&D in medical and health sciences in GDP (%): data from OECD (2022a) for 2010-2021 period [F],
- The share of patent publications in medical technology in total patent applications: WIPO (2022) for 2009-2020 period [G],
- Number of "Mammographs" per million population: data from OECD (2022a) for 2010-2021 period [H],
- Number of "Radiation Therapy Equipment" per million population: data from OECD (2022a) for 2010-2021 period [I],
- Number of "Gamma Cameras (Nuclear Medicine) Equipment" per million population: data from OECD (2022a) for 2010-2021 period [J],
- Number of "Positron Emission Tomography (PET) Scanners" per million population: data from OECD (2022a) for 2010-2021 period [K],
- Number of "Computed Tomography (CT) Scanners" per million population: data from OECD (2022a) for 2010-2021 period [L],
- Number of "Magnetic Resonance Imaging (MRI) Units" per million population: data from OECD (2022a) for 2010-2021 period [M],
- OECD export in medical technology (billion \$, FOB): data from OECD (2022a) for 2010-2021 period [N],
- OECD import in medical technology (billion \$, CIF): data from OECD (2022a) for 2010-2021 period [O].

## 2.2. Data selection

As the mentioned above there was a lack of data for some countries. The normality of the data is very important to analyse the data. The 22nd version of Statistical Package for Social Sciences Data (SPSS) (IBM 2022) was used to test the normality of the data, and to show the relationship between the indicators.

Kolmogorov-Smirnov (KS) and Shapiro-Wilks (SW) tests were used to check the normality of the data for fifteen indicators. The parametric Pearson correlation test should be used for the normally distributed data whereas the Spearman's rho non-parametric correlation test should be used for non-normally distributed data. To test the normality of the data, the null ( $H_0$ ) and alternative ( $H_1$ ) hypotheses are as:

$H_0$ : The data shows a normal distribution,

$H_1$ : The data does not show a normal distribution.

If the probability value ( $p$ ) is greater than the critical value (0.05), we are not able to reject the null hypothesis with 95% confidence, so that the data show a normal

distribution. If the probability value ( $p$ ) is smaller than the critical value (0.05), so we are able to reject the null hypothesis and accept the alternative one with 95% confidence, so that the data do not show a normal distribution.

### 3. Results

Patents are good innovation indicator for the firms at micro level and for sectors and countries at macro level. Increasing labour and capital in a production function will cause decreasing returns to scale whereas knowledge (know-how), skilled and talented human capital and innovation will cause increasing returns to scale. Technological improvements are mostly used in health sector to achieve a longer and healthy human life.

The share of health and social personnel in total employment was 9.9% in 2010 in OECD countries and increased to 10.7% in 2021. The share of health and social personnel in total employment was 2.85% in 2010 in Türkiye and increased to 5.11% in 2021.

The share of practising nurses in total health and social personnel was 18.3% in 2010, increased to 19.7% in pandemic period, and continued to increase to 20% in OECD in 2021. The share of practising nurses in total health and social personnel was 19% in 2010, decreased to 15.5% in Türkiye in 2021. In OECD, there were 979 and in Türkiye, there were 270 nurses per hundred thousand population in 2021. There were 227.3 thousand nurses in Türkiye in 2020 (Türkiye Ministry of Health 2022).

The share of practising physicians in total health and social personnel was 6% in 2010, increased to 6.23% in pandemic period, and continued to increase to 6.3% in OECD in 2021. The share of practising physicians in total health and social personnel was 20.9% in 2010, decreased to 11.7% in Türkiye in 2021. In OECD, there were 307 and in Türkiye, there were 204 practising physicians per hundred thousand population in 2021. There were 171.3 thousand practising physicians in Türkiye in 2020 (Türkiye Ministry of Health 2022) (**Table 1**).

Table 1 Health related indicators in OECD by year

Year	The share of health and social personnel in total employment (%)	The share of practising nurses in total health and social personnel (%)	The share of practising physicians in total health and social personnel (%)
2010	9.92	18.26	6.05
2011	10.03	18.10	6.08
2012	10.43	18.04	6.06
2013	10.59	17.83	6.09
2014	10.66	17.76	6.11
2015	10.81	17.54	6.06
2016	10.99	17.44	6.03
2017	11.00	18.70	6.06
2018	11.08	19.36	6.03
2019	11.14	19.31	6.09
2020	10.90	19.70	6.23
2021	10.74	20.02	6.28

Source: OECD (2022a), the WHO (2022)

Health expenditure per capita was 4,053 \$ in 2010 in OECD countries and increased to 5,322 \$ in 2020 and continued to increase to 5,598 \$ in 2021. Health expenditure per capita was 535 \$ in 2010 in Türkiye and increased to 398.3 \$ in 2020 and decreased to 312.6 \$ in 2021.

Health expenditure as a share of GDP was 11.5% in 2010 in OECD countries, increased to 13.9% in 2020, and decreased to 13.2% in 2021 due to the recovery and good economic performance (increasing Gross Domestic Product “GDP”) in the world. Health expenditure as a share of GDP was 5% in 2010 in Türkiye, decreased to 4.6% in 2020, and to 3.2% in 2021 due to the GDP increases.

Gross domestic expenditure share on R&D in medical and health sciences in GDP was 0.6% in 2010 in OECD countries, increased to 0.63% in 2020, and decreased to 0.56% in 2021 due to the increasing global GDP. Gross domestic expenditure share on R&D in medical and health sciences in GDP was 0.14% in 2010 in Türkiye, decreased to 0.13% in 2020, and to 0.09% in 2021 due to the having more GDP increase than the R&D expenditure increase in medical and health sciences (**Table 2**).

Table 2 Health expenditure, R&D and patents in medical technologies in OECD by year

Year	Health expenditure per capita (\$)	Health expenditure as a share of GDP (%)	Gross domestic expenditure share on R&D in medical and health sciences in GDP (%)
2010	4,052.71	11.54	0.60
2011	4,351.36	11.59	0.53
2012	4,363.69	11.73	0.54
2013	4,387.11	11.72	0.57
2014	4,509.85	11.87	0.58
2015	4,348.29	12.24	0.60
2016	4,479.60	12.40	0.62
2017	4,631.00	12.35	0.63
2018	4,854.07	12.32	0.63
2019	4,944.67	12.51	0.63
2020	5,322.71	13.91	0.63
2021	5,597.5	13.22	0.56

Source: OECD (2022a)

Number of "Mammographs" per million population in OECD countries was 26.3 in 2010 and 46.7 in 2021. Number of "Mammographs" per million population in Türkiye was 8.7 in 2010 and 11.7 in 2021. Türkiye has a worse performance comparing with OECD average at this medical technology.

Number of "Radiation Therapy Equipment" per million population in OECD countries was 6.9 in 2010 and 7.6 in 2021. Number of "Radiation Therapy Equipment" per million population in Türkiye was 1.8 in 2010 and 2.9 in 2021. Türkiye has a worse performance comparing with OECD average at this medical technology.

Number of "Gamma Cameras (Nuclear Medicine) Equipment" per million population in OECD countries was 20.4 in 2010 and 19.1 in 2021. Number of "Gamma Cameras (Nuclear Medicine) Equipment" per million population in Türkiye was 2.3 in 2010 and 3.2 in 2021. Türkiye has a worse performance comparing with OECD average at this medical technology.

Number of "Positron Emission Tomography (PET) Scanners" per million population in OECD countries was 2.4 in 2010 and 3.4 in 2021. Number of "Positron Emission Tomography (PET) Scanners" per million population in Türkiye was 0.55 in 2010 and 1.71 in 2021. Türkiye has a worse performance comparing with OECD average at this medical technology.

Number of "Computed Tomography (CT) Scanners" per million population in OECD countries was 31.7 in 2010 and 35.7 in 2021. Number of "Computed Tomography

(CT) Scanners" per million population in Türkiye was 12.4 in 2010 and 14.8 in 2021. Türkiye has a worse performance comparing with OECD average at this medical technology.

Number of "Magnetic Resonance Imaging (MRI) Units" per million population in OECD countries was 19.5 in 2010 and 25.1 in 2021. Number of "Magnetic Resonance Imaging (MRI) Units" per million population in Türkiye was 9.3 in 2010 and 11.2 in 2021. Türkiye has a worse performance comparing with OECD average at this medical technology (**Table 3**).

It seems that Türkiye has a worse performance to have medical technologies listed at the table below comparing with OECD average at this medical technology.

*Table 3 Medical technologies in OECD by year*

Year	Number of "Mammographs" per million population	Number of "Radiation Therapy Equipment" per million population	Number of "Gamma Cameras (Nuclear Medicine) Equipment" per million population	Number of "Positron Emission Tomography (PET) Scanners" per million population	Number of "Computed Tomography (CT) Scanners" per million population	Number of "Magnetic Resonance Imaging (MRI) Units" per million population
2010	26.34	6.91	20.40	2.44	31.65	19.45
2011	26.36	7.35	20.30	2.50	31.79	19.78
2012	27.05	7.34	20.22	2.70	32.98	20.77
2013	27.52	7.45	19.06	2.80	33.20	21.40
2014	28.10	7.47	18.93	2.92	33.29	22.88
2015	29.46	7.44	18.86	2.97	33.49	23.63
2016	30.95	7.68	18.73	3.01	33.88	23.30
2017	32.06	7.69	18.49	3.08	34.64	24.06
2018	33.39	7.57	18.37	3.20	35.22	24.60
2019	34.65	7.65	19.30	3.28	35.48	25.13
2020	35.70	7.61	19.16	3.40	35.49	24.11
2021	36.68	7.60	19.11	3.42	35.67	25.09

Source: OECD (2022a)

In 2010, global export value was 75 billion dollar and 88.7 percent of this export, which was 66.5 billion dollar, was made by OECD countries. Türkiye has 52.9 million dollar export value in medical technologies in 2010. In 2021, global export value has increased to 121.2 billion dollar and 83.5 percent of this export, which was 101.2 billion dollar, was made by OECD countries. Türkiye's export value has increased to 368 million dollar in medical technologies in 2021.

In 2010, global import value was 76 billion dollar and 73.5 percent of this import, which was 55.8 billion dollar, was made by OECD countries. Türkiye has 760.6 million

dollar import value in medical technologies in 2010. In 2021, global import value has increased to 124.8 billion dollar and 70.9 percent of this import, which was 88.5 billion dollar, was made by OECD countries (**Table 4**). Türkiye's import value has increased to 827.9 million dollar in medical technologies in 2021.

It seems that OECD countries are net exporter in total whereas Türkiye is a net importer in medical technology foreign trade. OECD's total foreign trade surplus was 12.7 billion dollar and Türkiye's foreign trade deficit was 460 million dollar in 2021.

*Table 4 Global foreign trade of OECD countries in total in medical technologies*

Year	Global export in medical technology (billion \$, FOB)	OECD export in medical technology (billion \$, FOB)	The share of OECD export in medical technology (%)	Global import in medical technology (billion \$, CIF)	OECD import in medical technology (billion \$, CIF)	Trade balance in medical technology (OECD, billion \$)	The share of OECD import in medical technology (%)
2010	75.0	66.5	88.7	76.0	55.8	10.7	73.5
2011	83.8	73.6	87.9	85.3	61.4	12.2	72.1
2012	86.0	74.6	86.7	88.4	61.6	12.9	69.7
2013	88.3	76.0	86.1	90.3	64.0	12.0	70.9
2014	91.9	78.8	85.7	93.3	66.7	12.1	71.4
2015	87.7	74.6	85.0	89.2	63.9	10.7	71.6
2016	89.4	76.3	85.4	91.4	66.2	10.1	72.4
2017	94.2	80.1	85.0	95.7	68.1	12.0	71.2
2018	102.5	87.1	85.0	105.8	75.3	11.8	71.2
2019	107.2	90.9	84.7	113.3	78.8	12.1	69.6
2020	108.0	90.1	83.5	113.7	80.5	9.6	70.8
2021	121.2	101.2	83.5	124.8	88.5	12.7	70.9

Source: ITC/TradeMap (2022)

In 2010, OECD total export value was 9.06 trillion dollar and 0.73 percent of this export, which was 66.5 billion dollar, was in medical technologies. Türkiye's total export value was 113.9 billion dollar and 0.05 percent of this export, which was 52.9 million dollars, was in medical technologies. In 2021, OECD total export value has increased to 12.3 trillion dollar and 0.82 percent of this export, which was 101.2 billion dollar, was in medical technologies. Türkiye's total export value was 225.3 billion dollar and 0.16 percent of this export, which was 368 million dollars, was in medical technologies.

In 2010, OECD total import value was 9.8 trillion dollar and 0.57 percent of this import, which was 55.8 billion dollar, was in medical technologies. Türkiye's total import value was 185.5 billion dollar and 0.41 percent of this import, which was 760.6 million dollars, was in medical technologies. In 2021, OECD total import value has increased to 13.4 trillion dollar and 0.66 percent of this import, which was 88.5 billion dollar, was in

medical technologies (**Table 5**). Türkiye's total import value was 271.4 billion dollar and 0.31 percent of this import, which was 827.9 million dollars, was in medical technologies.

It seems that, the share of export in medical technology in total OECD export is greater than the share of import in medical technology in total OECD import, whereas the share of export in medical technology in Türkiye's total export is smaller than the share of import in medical technology in Türkiye's total import. Both OECD and Türkiye have trade deficit in global trade during the 2010-2021 period.

*Table 5 The share of foreign trade in medical technologies in OECD's total foreign trade*

Year	OECD total export (billion \$)	OECD export in medical technology (billion \$, FOB)	The share of export in medical technology in total export (% , OECD)	OECD total import (billion \$)	OECD import in medical technology (billion \$, CIF)	The share of import in medical technology in total export (% , OECD)	Trade balance in OECD (billion \$)	Trade balance in medical technology (OECD, billion \$)
2010	9,058.9	66.5	0.73	9,762.6	55.8	0.57	-703.6	10.7
2011	10,600.7	73.6	0.69	11,509.8	61.4	0.53	-909.0	12.2
2012	10,444.7	74.6	0.71	11,323.3	61.6	0.54	-878.6	12.9
2013	10,720.1	76.0	0.71	11,363.1	64.0	0.56	-642.9	12.0
2014	10,800.9	78.8	0.73	11,512.2	66.7	0.58	-711.3	12.1
2015	9,533.8	74.6	0.78	10,156.8	63.9	0.63	-623.0	10.7
2016	9,405.9	76.3	0.81	9,987.9	66.2	0.66	-582.0	10.1
2017	10,258.7	80.1	0.78	10,931.1	68.1	0.62	-672.4	12.0
2018	11,176.4	87.1	0.78	11,995.6	75.3	0.63	-819.2	11.8
2019	10,874.3	90.9	0.84	11,641.3	78.8	0.68	-766.9	12.1
2020	9,985.0	90.1	0.90	10,797.0	80.5	0.75	-812.0	9.6
2021	12,269.4	101.2	0.82	13,400.7	88.5	0.66	-1,131.3	12.7

Source: ITC/TradeMap (2022)

In OECD, total export value in '901890 "Instruments and appliances used in medical, surgical or veterinary sciences. n.e.s." HS-6 digit product was 54.6 billion dollar and total import value was 50.7 billion dollar, which means that there is trade surplus in foreign trade of this medical technology in 2021. In OECD, total export value of this product was 53.8 percent of total export in medical technologies whereas total import value was 57.3 percent. For Türkiye, total export value of this product was 81.4 percent of total export in medical technologies whereas total import value was 54 percent. This product has higher foreign trade share in export than import in Türkiye.

In OECD, total export value in '901819 “Electro-diagnostic apparatus, incl. apparatus for functional exploratory examination or for checking physiological parameters (excluding electro-cardiographs, ultrasonic scanning apparatus, magnetic resonance imaging apparatus and scintigraphic apparatus).” HS-6 digit product was 14.1 billion dollar and total import value was 12.5 billion dollar, which means that there is trade surplus in foreign trade of this medical technology in 2021. In OECD, total export value of this product was 14 percent of total export in medical technologies whereas total import value was 14.1 percent. For Türkiye, total export value of this product was 2.1 percent of total export in medical technologies whereas total import value was 5.6 percent. This product has higher foreign trade share in import than export in Türkiye.

In OECD, total export value in '902290 “X-ray generators other than X-ray tubes, high tension generators, control panels and desks, screens, examination or treatment tables, chairs and the like, and general parts and accessories for apparatus of heading 9022, n.e.s.” HS-6 digit product was 6.1 billion dollar and total import value was 5.8 billion dollar, which means that there is trade surplus in foreign trade of this medical technology in 2021. In OECD, total export value of this product was 6.1 percent of total export in medical technologies whereas total import value was 6.5 percent. For Türkiye, total export value of this product was 2.3 percent of total export in medical technologies whereas total import value 4 percent. This product has higher foreign trade share in import than export in Türkiye.

In OECD, total export value in '902214 “Apparatus based on the use of X-rays, for medical, surgical or veterinary uses (excluding for dental purposes and computer tomography apparatus)” HS-6 digit product was 5.5 billion dollar and total import value was 3.7 billion dollar, which means that there is trade surplus in foreign trade of this medical technology in 2021. In OECD, total export value of this product was 5.4 percent of total export in medical technologies whereas total import value was 4.2 percent. For Türkiye, total export value of this product was 2.2 percent of total export in medical technologies whereas total import value 8.4 percent. This product has higher foreign trade share in import than export in Türkiye.

In OECD, total export value in '901813 “Magnetic resonance imaging apparatus” HS-6 digit product was 4.3 billion dollar and total import value was 3.6 billion dollar, which means that there is trade surplus in foreign trade of this medical technology in 2021. In OECD, total export value of this product was 4.3 percent of total export in medical technologies whereas total import value was 4 percent. For Türkiye, total export value of this product was 2.9 percent of total export in medical technologies whereas total import value 4.8 percent. This product has higher foreign trade share in import than export in Türkiye.

The first three medical technologies product ('901890, '901819 and '902290) export share was 74 percent in total medical technologies export in OECD in 2021, and for import, the share was 77.9 percent. These three products have more weight in import comparing with export in OECD (**Table 6**).

The first three medical technologies product ('901890, '901813 and '902212) export share was 87.1 percent in total medical technologies export in Türkiye in 2021, and for import of the first three products ('901890, '902214 and '901819), the share was 68 percent. These three products have more weight in import comparing with export for Türkiye.

*Table 6 Global foreign trade of OECD countries in total by product breakdown in medical technologies*

HS-6 digit product code	OECD export in medical technology (billion \$. FOB)	OECD import in medical technology (billion \$. FOB)	Trade balance in medical technology (billion \$)	Product's share in OECD export in medical technology (%)	Product's share in OECD import in medical technology (%)
'901890	54.6	50.7	3.9	53.9	57.3
'901819	14.1	12.5	1.6	14.0	14.1
'902290	6.1	5.8	0.4	6.1	6.5
'902214	5.5	3.7	1.7	5.4	4.2
'901813	4.3	3.6	0.8	4.3	4.0
'901850	4.3	3.3	1.0	4.2	3.7
'902212	4.0	2.6	1.4	3.9	2.9
'901812	3.8	2.9	1.0	3.8	3.2
'902219	2.2	1.3	0.9	2.2	1.5
'901811	0.9	1.1	-0.1	0.9	1.2
'901820	0.5	0.3	0.2	0.5	0.4
'901814	0.3	0.3	0.0	0.3	0.3
'902221	0.3	0.2	0.1	0.3	0.2
'902229	0.2	0.3	-0.1	0.2	0.4
	101.2	88.5	12.7	100.0	100.0

Source: ITC/TradeMap (2022)

United States has the highest “health expenditure per capita” and Türkiye has the lowest value and ranked 38th in this indicator in 2021.

Norway has the highest “the share of health and social personnel in total employment” and Mexico has the lowest value and Türkiye ranked 35th in this indicator in 2021.

Mexico has the highest “the share of practising nurses in total health and social personnel” and Colombia has the lowest value and Türkiye ranked 29th in this indicator in 2021.

Mexico has the highest “the share of practising physicians in total health and social personnel” and Luxembourg has the lowest value and Türkiye ranked 14th in this indicator in 2021.

United States has the highest “health expenditure as a share of GDP” and Türkiye has the lowest value and ranked 38th in this indicator in 2021.

United States has the highest “gross domestic expenditure share on R&D in medical and health sciences in GDP” and Luxembourg has the lowest value and Türkiye ranked 12th in this indicator in 2021.

Iceland has the highest “the share of patent publications in medical technology in total patent applications” and Slovakia has the lowest value and Türkiye ranked 26th in this indicator in 2021.

For medical technology usage in the countries, United States has the highest “number of mammographs per million population” and United Kingdom has the lowest value and Türkiye ranked 24th in this indicator in 2021.

Switzerland has the highest “number of Radiation Therapy Equipment per million population” and Chile has the lowest value and Türkiye ranked 27th in this indicator in 2021.

United States has the highest “number of Gamma Cameras (Nuclear Medicine) Equipment per million population” and Mexico has the lowest value and Türkiye ranked 26th in this indicator in 2021.

Denmark has the highest “number of Positron Emission Tomography (PET) Scanners per million population” and Mexico has the lowest value and Türkiye ranked 19th in this indicator in 2021.

Japan has the highest “number of Computed Tomography (CT) Scanners per million population” and Colombia has the lowest value and Türkiye ranked 28th in this indicator in 2021.

Japan has the highest “number of Magnetic Resonance Imaging (MRI) Units per million population” and Colombia has the lowest value and Türkiye ranked 25th in this indicator in 2021.

Considering the medical technology foreign trade of the countries, United States has the highest export value, Chile has the lowest value, and Türkiye ranked 24th in this indicator in 2021. United States has the highest import value and Iceland has the lowest value and Türkiye ranked 18th in this indicator in 2021 (**Table 7**).

Table 7 Best and worst performers in the indicators

Indicator	Number of OECD members which have data for medical technology	The country which has the highest number of medical technology per million population in 2021 or most recent year	The country which has the lowest number of medical technology per million population in 2021 or most recent year	Türkiye's ranking in having medical technology per million population in OECD countries
[A]	38	United States	Türkiye	38
[B]	38	Norway	Mexico	35
[C]	38	Mexico	Colombia	29
[D]	38	Mexico	Luxembourg	14
[E]	38	United States	Türkiye	38
[F]	18	United States	Luxembourg	12
[G]	38	Iceland	Slovakia	26
[H]	31	United States	United Kingdom	24
[I]	30	Switzerland	Chile	27
[J]	31	United States	Mexico	26
[K]	32	Denmark	Mexico	19
[L]	35	Japan	Colombia	28
[M]	33	Japan	Colombia	25
[N]	38	United States	Chile	24
[O]	38	United States	Iceland	18

Source: OECD (2022a), the WHO (2022)

## 2.1. Normality of the data

As mentioned above, according to the results of the normality tests, non-parametric tests should be applied for non-normally distributed data set especially to check the correlations between indicators. Kolmogorov-Smirnov and Shapiro-Wilk test results state that probability value ( $p$ ) is smaller than the critical value (0.05) for the indicators “the share of practising physicians in total health and social personnel (%) [D] and “number of "Radiation Therapy Equipment" per million population [I]” so that the null hypothesis should be rejected and the alternative one should be accepted with 95% confidence interval. The results show that these data are not normally distributed. As a result, Spearman's rho non-parametric correlation test should be used considering the normality tests result of both data.

Kolmogorov-Smirnov and Shapiro-Wilk test results state that probability value ( $p$ ) is greater than the critical value (0.05) for the indicators [A], [B], [C], [E], [F], [G], [H], [J], [K], [L], [M], [N] and [O] so that the null hypothesis cannot be rejected with 95% confidence interval. The results show that these data are normally distributed. As a result,

Pearson parametric correlation test should be used considering the normality tests result of these thirteen data set (**Table 8**).

*Table 8 Test of Normality*

Indicator	Kolmogorov-Smirnov			Shapiro-Wilk			Conclusion (normality)
	Statistic	df	Sig.	Statistic	df	Sig.	
[A]	0.209	12	0.155	0.898	12	0.148	Normal
[B]	0.149	12	,200*	0.898	12	0.149	Normal
[C]	0.192	12	,200*	0.910	12	0.214	Normal
[D]	0.288	12	0.007	0.759	12	0.003	Not normal
[E]	0.207	12	0.166	0.875	12	0.075	Normal
[F]	0.183	12	,200*	0.879	12	0.085	Normal
[G]	0.179	12	,200*	0.926	12	0.344	Normal
[H]	0.171	12	,200*	0.912	12	0.226	Normal
[I]	0.177	12	,200*	0.829	12	0.020	Not normal
[J]	0.218	12	0.120	0.875	12	0.076	Normal
[K]	0.097	12	,200*	0.957	12	0.733	Normal
[L]	0.159	12	,200*	0.917	12	0.262	Normal
[M]	0.173	12	,200*	0.897	12	0.147	Normal
[N]	0.196	12	,200*	0.927	12	0.347	Normal
[O]	0.214	12	0.135	0.930	12	0.385	Normal

Source: IBM (2022), EViews (2022)

## 2.2.The relationship between patent grants per million population and GDP per capita

In the study, 38 OECD countries were analysed. Spearman's rho non-parametric and Pearson parametric correlation tests were applied to test the normality of the data set.

It is found that a high positive correlation coefficient as 0.902 between “health expenditure per capita” and “the share of patent publications in medical technology in total patent applications”. Correlation is significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient as 0.928 between “health expenditure per capita” and “number of Mammographs per million population”. Correlation is significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient between “health expenditure per capita” and “OECD export in medical technology” as 0.976 and “OECD import in medical technology” as 0.984. Both correlations are significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient as 0.919 between “the share of health and social personnel in total employment” and “number of Magnetic Resonance Imaging (MRI) Units per million population”. Correlation is significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient between “the share of patent publications in medical technology in total patent applications” and “number of mammographs per million population” as 0.979, and “number of Positron Emission Tomography (PET) Scanners per million population” as 0.914, and “number of Computed Tomography (CT) Scanners per million population” as 0.909, and “OECD import in medical technology” as 0.917. All correlations are significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient between “number of mammographs per million population” as 0.960 and “number of Computed Tomography (CT) Scanners per million population” as 0.962, and “OECD export in medical technology” as 0.922 and “OECD import in medical technology” as 0.949. All correlations are significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient between “number of "Positron Emission Tomography (PET) Scanners" per million population” and " Number of "Computed Tomography (CT) Scanners" per million population” as 0.983 and “Number of "Magnetic Resonance Imaging (MRI) Units" per million population” as 0.956, and “OECD export in medical technology” as 0.902 and “OECD import in medical technology” as 0.927. All correlations are significant even at the 0.01 level (2-tailed).

There is a high positive correlation coefficient between “Number of "Computed Tomography (CT) Scanners" per million population” and “number of Magnetic Resonance Imaging (MRI) Units" per million population" as 0.945 and “OECD export in medical technology” as 0.902 and “OECD import in medical technology” as 0.917. All correlations are significant even at the 0.01 level (2-tailed).

The share of practising nurses in total health and social personnel has the highest positive correlation with “health expenditure per capita” as 0.868 and with “OECD export and import in medical technology as 0.851 and “the share of patent publications in medical technology in total patent applications” as 0.846.

Gross domestic expenditure share on R&D in medical and health sciences in GDP has the highest positive correlation with “the share of health and social personnel in total employment” as 0.692 and “number of Radiation Therapy Equipment per million population” as 0.667 and “number of Magnetic Resonance Imaging (MRI) Units per million population” as 0.611.

The share of practising physicians in total health and social personnel has the highest positive correlation with “OECD import in medical technology” as 0.498 and “OECD export in medical technology” as 0.478.

Health expenditure as a share of GDP has the highest positive correlation with “number of Mammographs" per million population” as 0.898 and “the share of patent publications in medical technology in total patent applications” as 0.886 and “health expenditure per capita” as 0.884 and “OECD import in medical technology” as 0.845, and

“number of Computed Tomography (CT) Scanners per million population” as 0.828 and “number of Radiation Therapy Equipment per million population” as 0.818 (**Table 9**).

Table 9 The correlation test results

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	1.000	0.550	0.868	0.509	0.884	0.233	0.902	0.928	0.741	-0.385	0.894	0.877	0.763	0.976	0.984
B	0.550	1.000	0.342	-0.099	0.591	0.692	0.654	0.743	0.839	-0.859	0.850	0.864	0.919	0.611	0.634
C	0.868	0.342	1.000	0.375	0.717	0.282	0.846	0.827	0.252	-0.154	0.701	0.749	0.572	0.851	0.851
D	0.509	-0.099	0.375	1.000	0.343	-0.238	0.233	0.375	0.117	0.293	0.375	0.375	0.290	0.478	0.495
E	0.884	0.591	0.717	0.343	1.000	0.459	0.886	0.898	0.818	-0.424	0.878	0.828	0.736	0.792	0.845
F	0.233	0.692	0.282	-0.238	0.459	1.000	0.547	0.543	0.667	-0.624	0.541	0.565	0.611	0.232	0.300
G	0.902	0.654	0.846	0.233	0.886	0.547	1.000	0.979	0.629	-0.520	0.914	0.909	0.852	0.884	0.917
H	0.928	0.743	0.827	0.375	0.898	0.543	0.979	1.000	0.776	-0.551	0.960	0.962	0.896	0.922	0.949
I	0.741	0.839	0.252	0.117	0.818	0.667	0.629	0.776	1.000	-0.587	0.776	0.776	0.734	0.764	0.762
J	-0.385	-0.859	-0.154	0.293	-0.424	-0.624	-0.520	-0.551	-0.587	1.000	-0.690	-0.672	-0.793	-0.432	-0.458
K	0.894	0.850	0.701	0.375	0.878	0.541	0.914	0.960	0.776	-0.690	1.000	0.983	0.956	0.902	0.927
L	0.877	0.864	0.749	0.375	0.828	0.565	0.909	0.962	0.776	-0.672	0.983	1.000	0.945	0.902	0.917
M	0.763	0.919	0.572	0.290	0.736	0.611	0.852	0.896	0.734	-0.793	0.956	0.945	1.000	0.815	0.834
N	0.976	0.611	0.851	0.478	0.792	0.232	0.884	0.922	0.764	-0.432	0.902	0.902	0.815	1.000	0.994
O	0.984	0.634	0.851	0.495	0.845	0.300	0.917	0.949	0.762	-0.458	0.927	0.917	0.834	0.994	1.000

Source: IBM (2022) N: number of observations

#### 4. Discussion and Conclusion

In this study the share of health expenditures in GDP in OECD countries has been estimated as 12.5 percent and has increased to 13.9 percent due to pandemic in 2020 and decreased to 13.2 due to the recovery in the economies in 2021. Due to the COVID-19 pandemic the health expenditures both of the government and citizens have increased in 2020. As a result of the recession in the economies GDP has contracted and the share of health expenditures in GDP in OECD countries increased from 8.8 percent in 2019 to 9.7 percent in 2020. The estimates for a group of 17 OECD countries in the OECD study show that healthcare spending continues to grow strongly in 2021, at around 6%. Due to the recovery in the economies globally and increasing GDP in 2021, health spending as a share of GDP is expected to decrease any 2021 (OECD 2022b).

Innovation is the core determinant of long-run economic growth and patents are one of the main indicators of innovation capability in a country. Innovation, is very important for both firms at micro level and countries at macro level to compete with competitors in international markets. Not only the income but patents are not distributed equally in the world. High-income countries have more income and patent grants in the world comparing with the low-income countries (Gürler 2022).

Today, where health expenditures are increasing rapidly, decision makers are trying to establish a balance between the right to access health and the financing of health

technologies (Yıldız 2018). In the study a positive correlation between health expenditure per capita and medical technologies but a negative correlation has found with “number of "Gamma Cameras (Nuclear Medicine) Equipment" per million population”.

It is thought that the share of the budget allocated to health services affects this, and it is seen that the countries that use medical technological devices the most in health services are developed countries (Kılıçarslan ve Takkasız 2019). There was unequal access to health personnel and medical technology, and this problem has increased with the pandemic. The health expenditure and human resources are not distributed equally in the world. In addition, foreign trade of technological medical devices used in the diagnosis of disease is distributed unequally too, since the purchasing power due to economic growth is not the same and sufficient resources are not allocated for R&D expenditures.

### Highlights

- The share of health and social personnel in total employment was 9.9% in 2010 in OECD countries and increased to 10.7% in 2021. The share of health and social personnel in total employment was 2.85% in 2010 in Türkiye and increased to 5.11% in 2021.
- The share of practising nurses in total health and social personnel was 18.3% in 2010, increased to 19.7% in pandemic period, and continued to increase to 20% in OECD in 2021. The share of practising nurses in total health and social personnel was 19% in 2010, decreased to 15.5% in Türkiye in 2021. In OECD, there were 979 and in Türkiye, there were 270 nurses per hundred thousand population in 2021. There were 227.3 thousand nurses in Türkiye in 2020 (Türkiye Ministry of Health 2022).
- The share of practising physicians in total health and social personnel was 6% in 2010, increased to 6.23% in pandemic period, and continued to increase to 6.3% in OECD in 2021. The share of practising physicians in total health and social personnel was 20.9% in 2010, decreased to 11.7% in Türkiye in 2021. In OECD, there were 307 and in Türkiye, there were 204 practising physicians per hundred thousand population in 2021. There were 171.3 thousand practising physicians in Türkiye in 2020 (Türkiye Ministry of Health 2022)
- Health expenditure per capita was 4,053 \$ in 2010 in OECD countries and increased to 5,322 \$ in 2020 and continued to increase to 5,598 \$ in 2021. Health expenditure per capita was 535 \$ in 2010 in Türkiye and increased to 398.3 \$ in 2020 and decreased to 312.6 \$ in 2021.
- Health expenditure as a share of GDP was 11.5% in 2010 in OECD countries, increased to 13.9% in 2020, and decreased to 13.2% in 2021 due to the

recovery and good economic performance (increasing Gross Domestic Product “GDP”) in the world. Health expenditure as a share of GDP was 5% in 2010 in Türkiye, decreased to 4.6% in 2020, and to 3.2% in 2021 due to the GDP increases.

- Gross domestic expenditure share on R&D in medical and health sciences in GDP was 0.6% in 2010 in OECD countries, increased to 0.63% in 2020, and decreased to 0.56% in 2021 due to the increasing global GDP. Gross domestic expenditure share on R&D in medical and health sciences in GDP was 0.14% in 2010 in Türkiye, decreased to 0.13% in 2020, and to 0.09% in 2021 due to the having more GDP increase than the R&D expenditure increase in medical and health sciences.
- It seems that Türkiye has a worse performance to have medical technologies listed at the table below comparing with OECD average at this medical technology.
- It seems that OECD countries are net exporter in total whereas Türkiye is a net importer in medical technology foreign trade. OECD’s total foreign trade surplus was 12.7 billion dollar and Türkiye’s foreign trade deficit was 460 million dollar in 2021.
- It seems that, the share of export in medical technology in total OECD export is greater than the share of import in medical technology in total OECD import, whereas the share of export in medical technology in Türkiye’s total export is smaller than the share of import in medical technology in Türkiye’s total import. Both OECD and Türkiye have trade deficit in global trade during the 2010-2021 period.
- The first three medical technologies product ('901890, '901819 and '902290) export share was 74 percent in total medical technologies export in OECD in 2021, and for import, the share was 77.9 percent. These three products have more weight in import comparing with export in OECD.
- The first three medical technologies product ('901890, '901813 and '902212) export share was 87.1 percent in total medical technologies export in Türkiye in 2021, and for import of the first three products ('901890, '902214 and '901819), the share was 68 percent. These three products have more weight in import comparing with export for Türkiye.
- Considering the medical technology foreign trade of the countries, United States has the highest export value, Chile has the lowest value, and Türkiye ranked 24th in this indicator in 2021. United States has the highest

import value and Iceland has the lowest value and Türkiye ranked 18th in this indicator in 2021.

- It is found that a high positive correlation coefficient as 0.902 between “health expenditure per capita” and “the share of patent publications in medical technology in total patent applications”. Correlation is significant even at the 0.01 level (2-tailed).
- There is a high positive correlation coefficient as 0.928 between “health expenditure per capita” and “number of Mammographs per million population”. Correlation is significant even at the 0.01 level (2-tailed).
- There is a high positive correlation coefficient between “health expenditure per capita” and “OECD export in medical technology” as 0.976 and “OECD import in medical technology” as 0.984. Both correlations are significant even at the 0.01 level (2-tailed).
- There is a high positive correlation coefficient as 0.919 between “the share of health and social personnel in total employment” and “number of Magnetic Resonance Imaging (MRI) Units per million population”. Correlation is significant even at the 0.01 level (2-tailed).

## 5. Acknowledge

### Study limitations

There was a missing data for the indicators apart from export and import values for some years.

### Disclosure

Authors have no conflict of interests, and the work was not supported or funded by any drug company. This paper has not been previously published and is not currently under consideration for publication elsewhere.

### Authors' contributions

All authors analysed and interpreted the data and wrote the manuscript together. All authors read and approved the final manuscript.

*Table 10 Author's' contributions*

Contribution	Dr. Özlem Özsoy
Conception or design of the work	Yes
Data collection	Yes
Data analysis and interpretation	Yes
Drafting the article	Yes
Critical revision of the article	Yes
Final approval of the submitted version	Yes

### Availability of data and material

Data sources are indicated in the study and data can be provided if needed. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Ethical statement

No ethical approval is needed for the study since it does not depend on outcomes from studies involving related data with humans or animals.

### Short bibliographies

Özlem ÖZSOY had received her bachelor's degree from Ege University School of Nursing in 1999 and her MA from the Department of Public Health Nursing at Ege University Health Sciences Institute in 2003. She completed her PhD in 2011 at the Department of Public Health Nursing at Ege University Health Sciences Institute. She worked at Ege University School of Nursing between 2001-2003 and at İstinye University between 2016-2018 as a lecturer. Since 2004, she has served in various positions related to management in private hospitals and she is still working as Director of Nursing Services in a private hospital. Health Management, Peer Education, Family Planning, Cervical Cancers, Performance Evaluation, Geriatrics are main research areas of Dr. Özlem Özsoy.

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## APPENDIX

Table 11 OECD countries

	Country		Country
1	Australia	20	Japan
2	Austria	21	Korea Republic
3	Belgium	22	Latvia
4	Canada	23	Lithuania
5	Chile	24	Luxembourg
6	Colombia	25	Mexico
7	Costa Rica	26	Netherlands
8	Czechia (Czech Republic)	27	New Zealand
9	Denmark	28	Norway
10	Estonia	29	Poland
11	Finland	30	Portugal
12	France	31	Slovakia (Slovak Republic)
13	Germany	32	Slovenia
14	Greece	33	Spain
15	Hungary	34	Sweden
16	Iceland	35	Switzerland
17	Ireland	36	Türkiye
18	Israel	37	United Kingdom
19	Italy	38	United States

Source: OECD (2022c)

Table 12 HS-6 digit classified products used for diagnostic purposes in medical technologies

HS-6 digit product code	Product detail
'901890	Instruments and appliances used in medical, surgical or veterinary sciences, n.e.s.
'901819	Electro-diagnostic apparatus, incl. apparatus for functional exploratory examination or for checking physiological parameters (excluding electro-cardiographs, ultrasonic scanning apparatus, magnetic resonance imaging apparatus and scintigraphic apparatus)
'902290	X-ray generators other than X-ray tubes, high tension generators, control panels and desks, screens, examination or treatment tables, chairs and the like, and general parts and accessories for apparatus of heading 9022, n.e.s.
'902214	Apparatus based on the use of X-rays, for medical, surgical or veterinary uses (excluding for dental purposes and computer tomography apparatus)
'901813	Magnetic resonance imaging apparatus
'901850	Ophthalmic instruments and appliances, n.e.s.
'902212	Computer tomography apparatus
'901812	Ultrasonic scanning apparatus
'902219	Apparatus based on the use of X-rays (other than for medical, surgical, dental or veterinary, surgical, dental or veterinary uses)
'901811	Electro-cardiographs
'901820	Ultraviolet or infra-red ray apparatus used in medical, surgical, dental or veterinary sciences
'901814	Scintigraphic apparatus
'902221	Apparatus based on the use of alpha, beta, gamma or other ionising radiation, for medical, surgical, dental or veterinary uses
'902229	Apparatus based on the use of alpha, beta, gamma or other ionising radiation (other than for medical, surgical, dental or veterinary uses)
	Total

Source: ITC/TradeMap (2022)