Radiotherapy and Oncology 112 (2014) 178–186

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

ESTRO-HERO survey

Radiotherapy staffing in the European countries: Final results from the ESTRO-HERO survey

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ARTICLE INFO

Article history:
Received 20 August 2014
Accepted 21 August 2014

Keywords:
Radiotherapy
Resources
Staffing
Europe

ABSTRACT

Background: The ESTRO Health Economics in Radiation Oncology (HERO) project has the overall aim to develop a knowledge base of the provision of radiotherapy in Europe and build a model for health economic evaluation of radiation treatments at the European level. The first milestone was to assess the availability of radiotherapy resources within Europe. This paper presents the personnel data collected in the ESTRO HERO database.

Materials and methods: An 84-item questionnaire was sent out to European countries, through their national scientific and professional radiotherapy societies. The current report includes a detailed analysis of radiotherapy staffing (questionnaire items 47–60), analysed in relation to the annual number of treatment courses and the socio-economic status of the countries. The analysis was conducted between February and July 2014, and is based on validated responses from 24 of the 40 European countries defined by the European Cancer Observatory (ECO).

Results: A large variation between countries was found for most parameters studied. Averages and ranges for personnel numbers per million inhabitants are 12.8 (2.5–30.9) for radiation oncologists, 7.6 (0–19.7) for medical physicists, 3.5 (0–12.6) for dosimetrists, 26.6 (1.9–78) for RTTs and 14.8 (0.4–61.0) for radiotherapy nurses. The combined average for physicists and dosimetrists is 9.8 per million inhabitants and 36.9 for RTT and nurses. Radiation oncologists on average treat 208.9 courses per year (range: 99.9–348.8), physicists and dosimetrists conjointly treat 303.3 courses (range: 85–757.7) and RTT and nurses 76.8 (range: 25.7–156.8). In countries with higher GNI per capita, all personnel categories treat fewer courses per annum than in less affluent countries. This relationship is most evident for RTTs and nurses. Different clusters of countries can be distinguished on the basis of available personnel resources and socio-economic status.

Conclusions: The average personnel figures in Europe are now consistent with, or even more favourable than the QUARTS recommendations, probably reflecting a combination of better availability as such, in parallel with the current use of more complex treatments than a decade ago. A considerable variation in available personnel and delivered courses per year however persists among the highest and lowest staffing levels. This not only reflects the variation in cancer incidence and socio-economic determinants, but also the stage in technology adoption along with treatment complexity and the different professional roles and responsibilities within each country. Our data underpin the need for accurate prediction models and long-term education and training programmes.

Radiotherapy is labour intensive due to its technological complexity and the associated challenge of maintaining accuracy and safety along the entire treatment pathway. The diverse patient population presenting with a spectrum of tumour sites, stages and treatment intent and with various co-morbidities, psychological and social status adds further layers of complexity. Radiotherapy therefore requires highly qualified personnel from different professional backgrounds, who must interact effectively and speak

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http://dx.doi.org/10.1016/j.radonc.2014.08.034
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the same 'language'. This necessitates long-term investment in and planning of education and training.

The European cancer landscape is highly diverse with large differences amongst countries in terms of population density, cancer incidence, economic context, staffing structure and defined roles and responsibilities [1,2]. These factors must all be considered when forecasting radiotherapy personnel requirements. The rapid change in technology and the introduction of new techniques with increased time and resource demands add to the complexity of the task [3–5].

The ESTRO-HERO (Health Economics in Radiation Oncology) project is building a health economics platform aimed at supporting the European radiotherapy community in developing and sustaining optimal radiotherapy services, consistent with evidence-based radiotherapy requirements and with structural, epidemiological and socio-economic determinants by country [6]. By providing an updated and validated description of European radiotherapy resources in collaboration with the national scientific and professional radiotherapy societies, and through the development of web-based cost and cost-effectiveness models, ESTRO will give European countries and their radiotherapy societies the possibility to benchmark their position in Europe and to compute the cost and cost-effectiveness of radiotherapy in their specific economic context.

The first phase of the HERO programme sets the scene by providing a blueprint of European radiotherapy based on a survey of resource availability (departments, equipment and personnel), guidelines and reimbursement. This paper reports findings regarding personnel while companion papers focus on equipment and guidelines [7,8].

Materials and methods

A web-based questionnaire consisting of 84 questions relating to population and cancer incidence, radiotherapy courses and resources, guidelines and reimbursement was developed and distributed to national scientific and professional radiotherapy societies (further referred to as "National Societies"). The full details of the data collected, the methodological considerations and the practical decisions regarding the data set used for the entire analysis, are described in the Supplementary material.

The current report presents a detailed analysis of radiotherapy staffing (questionnaire items 47–60) in countries defined by the European Cancer Observatory [1]. Among the 34 ECO countries responding to the questionnaire, 10 could not be included in this analysis of staffing: 9 countries provided insufficient data, did not submit updates or did not give their assent to use their previous submission, and 1 country returned non-compliant personnel data (minimum thresholds instead of actual figures). The partial or complete data sets regarding personnel resources in the remaining 24 ECO countries form the basis of the present analysis (Table 1). Data from the United Kingdom were calculated by pooling together the data from the four separate countries, when available.

Personnel resources were reviewed for radiation oncologists (RO), medical physicists (MP or physicists), dosimetrists (DO), radiation therapists (RTT), radiotherapy nurses (RN or nurses) and radiobiologists, both for the public and private sector, excluding trainees. Actual numbers and full time equivalents (FTE) were collected. Guidelines being typically defined for personnel numbers and uncertainties being recognised in the FTE data, the actual numbers were used for the calculation of the key indicators, except for countries only providing FTE, where these were used as a proxy.

The number of delivered radiotherapy treatment courses – radical, palliative, or re-treatment – was recorded in the questionnaire. For the 8 countries where the information about retreatments was unavailable, the primary treatment figures were augmented with 25% [9–11].

The economic status of the countries was expressed as gross national income per capita (GNI/n; in US$ according to World Bank standards) using the Atlas method [2].

In order to identify relatively homogeneous groups of countries based on selected characteristics of personnel per million inhabitants (RO, MP + DO, RTT + RN) and of GNI/n, the k-means clustering via principal components analysis using the Hartigan and Wong method was applied [12]. With this method, multidimensional data can be represented into two axes and cluster centroids defined (vector of mean values of each variable). The statistical software R was used to perform this analysis [13].

Results

Validated data on radiotherapy courses and personnel categories (actual numbers and FTE) in the 24 countries are shown in Table 1. Large ranges in personnel numbers are observed, related to the size of the country and to the other determinants discussed below.

Demographic indicators

Table 2 gives an overview of the numbers of personnel per million inhabitants. Average values for the available countries are 12.8 for radiation oncologists, 7.6 for physicists, 3.5 for dosimetrists, 26.6 for RTT and 14.8 for nurses, but with very large variation between minima and maxima. Combining personnel categories performing similar tasks in the radiotherapy process has little impact on this variability. Averages are 9.8 per million inhabitants for physicists and dosimetrists, 36.9 for RTTs and nurses. Fig. 1a–c represents these data graphically.

Some countries (e.g., Albania, Hungary, Bulgaria) have low staffing levels overall; others, such as Denmark, Norway and The Netherlands, typically have higher levels, but not necessarily for all personnel categories. The lowest levels of physics (including dosimetry) staff are seen in countries that do not have (recognised) dosimetrists. In The Netherlands, for example, RTTs take up a large share of the planning responsibilities, but they are not referred to as dosimetrists, hence are not accounted for in the physics staff. As nurses operate the machines in Belgium, Denmark and Iceland, staffing levels are low for RTTs and high for nurses in these countries.

Annual courses per personnel

Table 2 also presents the annual courses per personnel type. The average country figures are 208.9 for radiation oncologists, 356.0 for physicists, 1,187.2 for dosimetrists, 208.0 for RTTs and 647.3 for nurses. Ranges between extremes decrease but remain large after combining physicists and dosimetrists (range: 85–757.7; average: 303.3 annual courses) and RTTs and nurses (range: 25.7–156.8; average: 76.8 courses). Fig. 2a–c shows these data graphically.

A few countries have consistently either high (e.g., Albania) or low (e.g., Denmark) numbers of courses per personnel, but in most countries the picture is more variable. In many countries, radiation oncologists are responsible for chemotherapy delivery as well [8], translating into low numbers of annual courses compared to the other professionals, as can for example be observed for the Czech Republic. If RTTs are responsible for planning, as in The Netherlands, annual courses for RTTs and nurses will be low and figures for physicists high.

Table 1
Validated data set on radiotherapy courses and personnel (number and FTE) by country, along with population and economic determinants.

Countries	Population (*2011*)	GNI per capita (*USD, 2011*)	Ref. year courses	RT courses	Ref. year staffing	Radiation oncologists		Medical physicists		Dosimetrists		Radiation technologists		Radiotherapy nurses		Radio-biologists	
						N	FTE	*N*	FTE	*N*	FTE	*N*	FTE	*N*	FTE	*N*	FTE
Albania	2,829,337	4,050	2010	2,195	2010	**7**	7.0	**6**	6.0	n.a.	n.a.	**13**	13.0	**1**	1.0	**n.a.**	n.a.
Austria	8,406,187	48,170	2010	21,481	2010 2013	**n.r.**	95.0	**n.r.**	40.0	n.a.	n.a.	**301**	280.0	**n.a.**	n.a.	**n.r.**	8.0
Belarus	9,473,000	6,270	2009	n.r.	2009	**117**	n.r.	**60**	n.r.	20	n.r.	**140**	n.r.	**150**	n.r.	**n.a.**	n.a.
Belgium	11,047,744	45,840	2012	34,672	2013	**154**	138.5	**113**	107.9	52	45.3	**21**	20.6	**471**	403.1	**4**	4.0
Bulgaria	7,348,328	6,640	2012	13,794	2012	**n.r.**	49.0	**n.r.**	23.0	n.a.	n.a.	**n.r.**	113.0	**n.r.**	98.0	**n.a.**	n.a.
Czech Republic	10,496,088	18,720	2009	32,630	2009	**254**	n.r.	**56**	n.r.	n.a.	n.a.	**251**	n.r.	**n.r.**	n.r.	**20**	n.r.
Denmark	5,570,572	60,160	2010	17,680	2010	**n.r.**	172.0	**n.r.**	89.0	n.r.	15.0	**n.r.**	55.0	**n.r.**	340.0	**n.r.**	1.0
Estonia	1,327,439	15,260	2008	2,122	2012	**14**	14.0	**10**	10.0	1	1.0	**16**	16.0	**6**	6.0	**n.r.**	n.r.
France	65,343,588	42,690	2012	187,172	2012	**670**	510.0	**n.r.**	528.0	n.r.	342.0	**n.r.**	1,950.0	**n.r.**	n.r.	**25**	n.r.
Hungary	9,971,727	12,840	2011	19,951	2011	**90**	n.r.	**60**	n.r.	8	n.r.	**207**	n.r.	**n.r.**	n.r.	**3**	n.r.
Iceland	319,014	35,260	2010	595	2010	**3**	2.6	**3**	2.2	4	3.0	**1**	0.8	**10**	7.0	**n.r.**	n.r.
Ireland	4,576,794	38,960	2009	8,373	2009	**30**	30.0	**54**	54.0	12	12.0	**291**	249.0	**35**	35.0	**n.a.**	n.a.
Lithuania	3,028,115	13,000	2011	6,268	2011	**37**	35.5	**31**	27.0	5	5.0	**70**	67.0	**10**	10.0	**1**	0.5
Luxembourg	518,347	77,380	2010	1,180	2011	**5**	4.9	**4**	4.0	3	2.5	**14**	13.5	**2**	2.0	**n.a.**	n.a.
Malta	416,268	19,780	2012	1,395	2012	**4**	4.0	**3**	3.0	0[a]	0.0[a]	**8**	8.0	**2**	2.0	**n.a.**	n.a.
Montenegro	620,644	6,810	2011	1,500	2011	**6**	5.0	**0**[a]	0.0[a]	n.a.	n.a.	**4**	4.0	**11**	11.0	**n.a.**	n.a.
The Netherlands	16,693,074	49,660	2011	55,683	2011	**256**	231.0	**119**	115.0	n.a.	n.a.	**1,302**	1,079.0	**n.a**	n.a	**n.r.**	n.r.
Norway	4,953,088	88,500	2010	13,483	2011	**n.r.**	135.0	**n.r.**	46.0	n.a.	n.a.	**n.r.**	267.0	**n.a**	n.a	**n.r.**	n.r.
Poland	38,534,157	12,340	2010	73,500	2012	**471**	471.0	**97**	97.0	n.a.	n.a.	**900**	900.0	**19**	19.0	**n.r.**	n.r.
Portugal	10,557,560	21,420	2012	19,858	2013	**90**	n.r.	**65**	n.r.	53	n.r.	**239**	n.r.	**108**	n.r.	**2**	n.r.
Slovenia	2,052,843	23,940	2012	6,023	2013	**31**	27.0	**11**	11.0	10	10.0	**81**	78.5	**n.a.**	n.a.	**n.a.**	n.a.
Spain	46,742,697	30,930	2011	98,525	2013	**702**	579.0	**282**	n.r.	249	n.r.	**n.r.**	n.r.	**n.r.**	n.r.	**n.r.**	n.r.
Switzerland	7,912,398	76,350	2009	19,000	2009	**110**	98.3	**83**	75.3	7	6.0	**312**	274.0	**110**	72.3	**3**	3.0
United Kingdom	63,258,918	37,840	2010 2011	n.r.	2010 2011	**683**	580.3	**1,246**	1,264.6	43	41.7	**2,763**	2,957.2	**403**	440.0	**22**	2.0
England	52,234,045	n.a.	2010	121,289	2010	**561**	482.0	**1,206**	1,096.7	n.a.	n.a.	**2,222**	2,468.0	**388**	437.0	**20**	n.r.
Scotland	5,254,800	n.a.	2011	n.r.	2011	**61**	58.75	**143**	133.0	n.a.	n.a.	**267**	243.6	**12**	n.r.	**n.a.**	n.a.
Wales	3,060,000	n.a.	2011	6,445	2011	**42**	39.5	**27**	24.9	27	25.7	**187**	163.2	**3**	3.0	**n.a.**	n.a.
Northern Ireland	1,800,000	n.a.	2010	4,180	2011	**19**	n.r.	**13**	10.0	16	16.0	**87**	82.4	**n.r.**	n.r.	**2**	2.0
No. entries	24	24	24	22	24	**20**	20	**19**	19	22	20	**19**	19	**18**	18	**16**	14
Total	331,997,927			635,179		**3,734**	3,189.1	**2,303**	2,503.0	467	483.5	**6,934**	8,345.6	**1,338**	1,446.4	**80**	18.5
Average	13,833,247	33,034	2010	28,872	2011	**187**	159.5	**121**	131.7	33	40.3	**365**	439.2	**96**	103.3	**10**	3.1
Median	7,630,363	27,435	2010	15,737	2011	**90**	72.0	**56**	40.0	9	8.0	**140**	78.5	**15**	15.0	**3**	2.5
Min	319,014	4,050	2008	595	2009	**3**	2.6	**0**	0.0	0	0.0	**1**	0.8	**1**	1.0	**1**	0.5
Max	65,343,588	88,500	2012	187,172	2013	**702**	580.3	**1,246**	1,264.6	249	342.0	**2,763**	2,957.2	**471**	440.0	**25**	8.0

n.r. = not reported; n.a. = not applicable.
Figures are rounded to the closest decimal number. Computation of totals, medians and ranges are for the available countries and use UK total figures, except for RT courses.
[a] Montenegro reported 0 MP although the position exists. There are to date no specialists, but 3 MP trainees. In Malta there are no dosimetrists although the position exists.

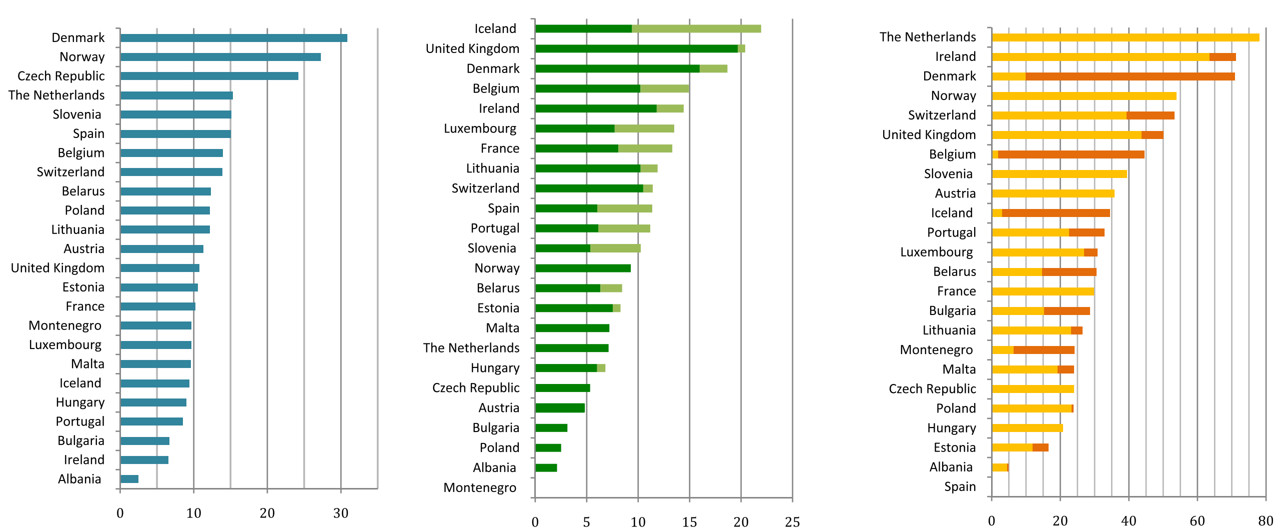
Table 2
Key indicators for different personnel categories (expressed in numbers).

Countries	Personnel type/million inhabitants							Courses/personnel type						
	RO	MP	DO	MP + DO	RTT	RN	RTT + RN	RO	MP	DO	MP + DO	RTT	RN	RTT + RN
Albania	**2.5**	2.1	n.a.	**2.1**	4.6	0.4	**4.9**	**313.6**	365.8	n.a.	**365.8**	168.8	2,195.0	**156.8**
Austria	**11.3**	4.8	n.a.	**4.8**	35.8	n.a.	**35.8**	**226.1**	537.0	n.a.	**537.0**	71.4	n.a.	**71.4**
Belarus	**12.4**	6.3	2.1	**8.4**	14.8	15.8	**30.6**	**–**	–	–	**–**	–	–	**–**
Belgium	**13.9**	10.2	4.7	**14.9**	1.9	42.6	**44.5**	**225.1**	306.8	666.8	**210.1**	1651.0	73.6	**70.5**
Bulgaria	**6.7**	3.1	n.a.	**3.1**	15.4	13.3	**28.7**	**281.5**	599.7	n.a.	**599.7**	122.1	140.8	**65.4**
Czech Republic	**24.2**	5.3	n.a.	**5.3**	23.9	–	**23.9**	**128.5**	582.7	n.a.	**582.7**	130.0	–	**130.0**
Denmark	**30.9**	16.0	2.7	**16.0**	9.9	61.0	**70.9**	**102.8**	198.7	1,178.7	**198.7**	321.5	52.0	**44.8**
Estonia	**10.5**	7.5	0.8	**8.3**	12.1	4.5	**16.6**	**151.6**	212.2	2,122.0	**192.9**	132.6	353.7	**96.5**
France	**10.3**	8.1	5.2	**13.3**	29.8	–	**29.8**	**279.4**	354.5	547.3	**215.1**	96.0	–	**96.0**
Hungary	**9.0**	6.0	0.8	**6.8**	20.8	–	**20.8**	**221.7**	332.5	2,493.9	**293.4**	96.4	–	**96.4**
Iceland	**9.4**	9.4	12.5	**21.9**	3.1	31.3	**34.5**	**198.3**	198.3	148.8	**85.0**	595.0	59.5	**54.1**
Ireland	**6.6**	11.8	2.6	**14.4**	63.6	7.6	**71.2**	**279.1**	155.0	697.7	**126.9**	28.8	239.2	**25.7**
Lithuania	**12.2**	10.2	1.7	**11.9**	23.1	3.3	**26.4**	**169.4**	202.2	1,253.6	**174.1**	89.5	626.8	**78.4**
Luxembourg	**9.6**	7.7	5.8	**13.5**	27.0	3.9	**30.9**	**236.0**	295.0	393.3	**168.6**	84.3	590.0	**73.8**
Malta	**9.6**	7.2	0.0	**7.2**	19.2	4.8	**24.0**	**348.8**	465.0	–	**465.0**	174.4	697.5	**139.5**
Montenegro	**9.7**	0.0	n.a.	**0.0**	6.4	17.7	**24.2**	**250.0**	–	n.a.	**–**	375.0	136.4	**100.0**
The Netherlands	**15.3**	7.1	n.a.	**7.1**	78.0	n.a.	**78.0**	**217.5**	467.9	n.a.	**467.9**	42.8	n.a.	**42.8**
Norway	**27.3**	9.3	n.a.	**9.3**	53.9	n.a.	**53.9**	**99.9**	293.1	n.a.	**293.1**	50.5	n.a.	**50.5**
Poland	**12.2**	2.5	n.a.	**2.5**	23.4	0.5	**23.8**	**156.1**	757.7	n.a.	**757.7**	81.7	3,868.4	**80.0**
Portugal	**8.5**	6.2	5.0	**11.2**	22.6	10.2	**32.9**	**199.5**	276.3	338.8	**152.2**	75.1	166.3	**51.7**
Slovenia	**15.1**	5.4	4.9	**10.2**	39.5	n.a.	**39.5**	**194.3**	547.5	602.3	**286.8**	74.4	n.a.	**74.4**
Spain	**15.0**	6.0	5.3	**11.4**	–	–	**–**	**140.3**	349.4	395.7	**185.5**	–	–	**–**
Switzerland	**13.9**	10.5	0.9	**11.4**	39.4	13.9	**53.3**	**172.7**	228.9	2,714.3	**211.1**	60.9	172.7	**45.0**
United Kingdom	**10.8**	19.7	0.7	**20.4**	43.7	6.4	**50.1**	**212.1**	105.9	3,067.8	**102.3**	52.8	337.4	**45.7**
England	**10.7**	23.1	n.a.	**23.1**	42.5	7.4	**50.0**	**216.2**	100.6	n.a.	**100.6**	54.6	312.6	**46.5**
Scotland	**11.6**	27.2	n.a.	**27.2**	50.8	2.3	**53.1**	**–**	–	–	**–**	–	–	**–**
Wales	**13.7**	8.8	8.8	**17.6**	61.1	1.0	**62.1**	**153.5**	238.7	238.7	**119.4**	34.5	2,148.3	**33.9**
Northern Ireland	**10.6**	7.2	8.9	**16.1**	48.3	–	**48.3**	**220.0**	321.5	261.3	**144.1**	48.0	–	**48.0**
No. entries	**24**	24	24	**24**	23	20	**23**	**23**	22	22	**22**	22	19	**22**
Average	**12.8**	7.6	3.5	**9.8**	26.6	14.8	**36.9**	**208.9**	356.0	1,187.2	**303.3**	208.0	647.3	**76.8**
Median	**11.0**	7.2	2.7	**9.8**	23.1	8.9	**30.9**	**212.1**	319.7	682.2	**213.1**	92.8	239.2	**72.6**
Min	**2.5**	0.0	0.0	**0.0**	1.9	0.4	**4.9**	**99.9**	105.9	148.8	**85.0**	28.8	52.0	**25.7**
Max	**30.9**	19.7	12.6	**21.9**	78.0	61.0	**78.0**	**348.8**	757.7	3,067.8	**757.7**	1651.0	3,868.4	**156.8**

n.r. = not reported; n.a. = not applicable.
Figures are rounded to the closest decimal number. Computation of totals, medians and ranges are for the available countries and use UK total figures, except for RT courses/personnel.

Economic indicators

Fig. 3a–c depicts the courses delivered per grouped personnel category in relation to the GNI/*n* of the country. Professionals in countries with higher GNI/*n* treat fewer courses per annum than personnel in countries where GNI/*n* is low. This relationship is most evident for RTTs combined with nurses and less so for radiation oncologists, which suggests that the relationship is also influenced by other factors.



a. ROs per million inhabitants

b. MPs and DOs per million inhabitants
MP: dark green – DO: light green

c. RTTs and RNs per million inhabitants
RTT: yellow – RN: orange

Fig. 1. Numbers of different personnel categories per million inhabitants.

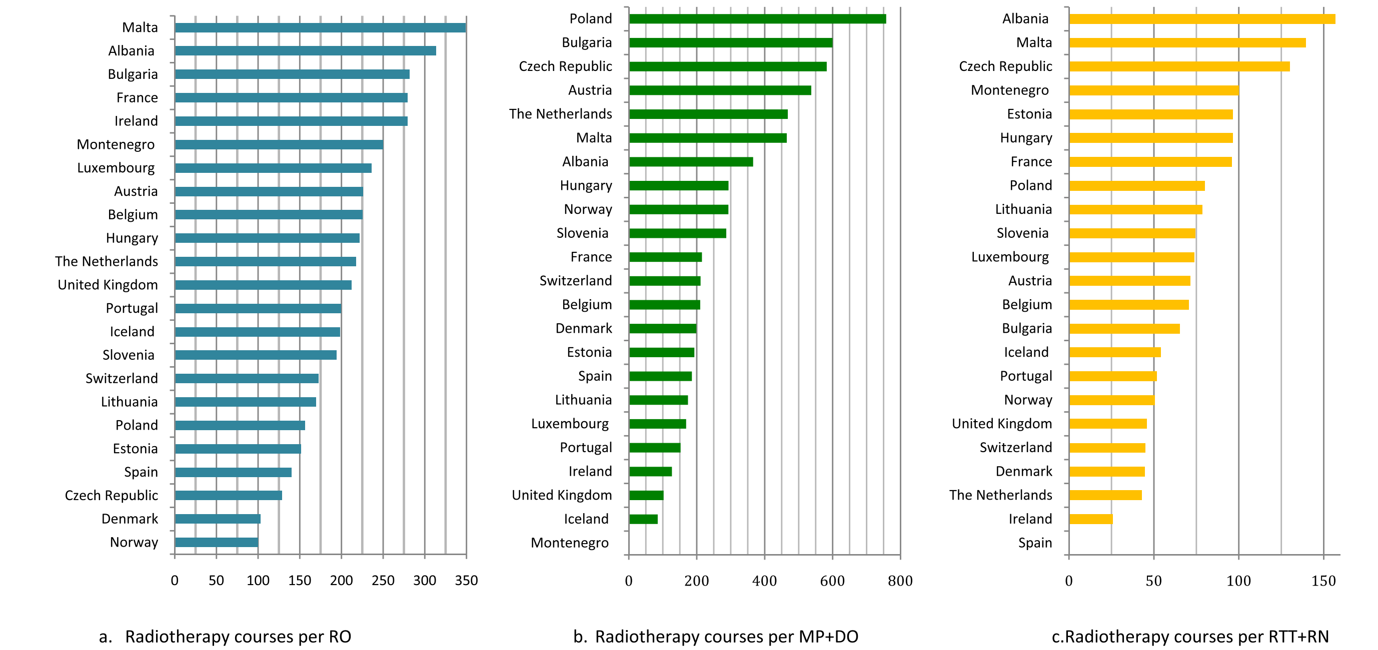


Fig. 2. Radiotherapy courses per different personnel categories.

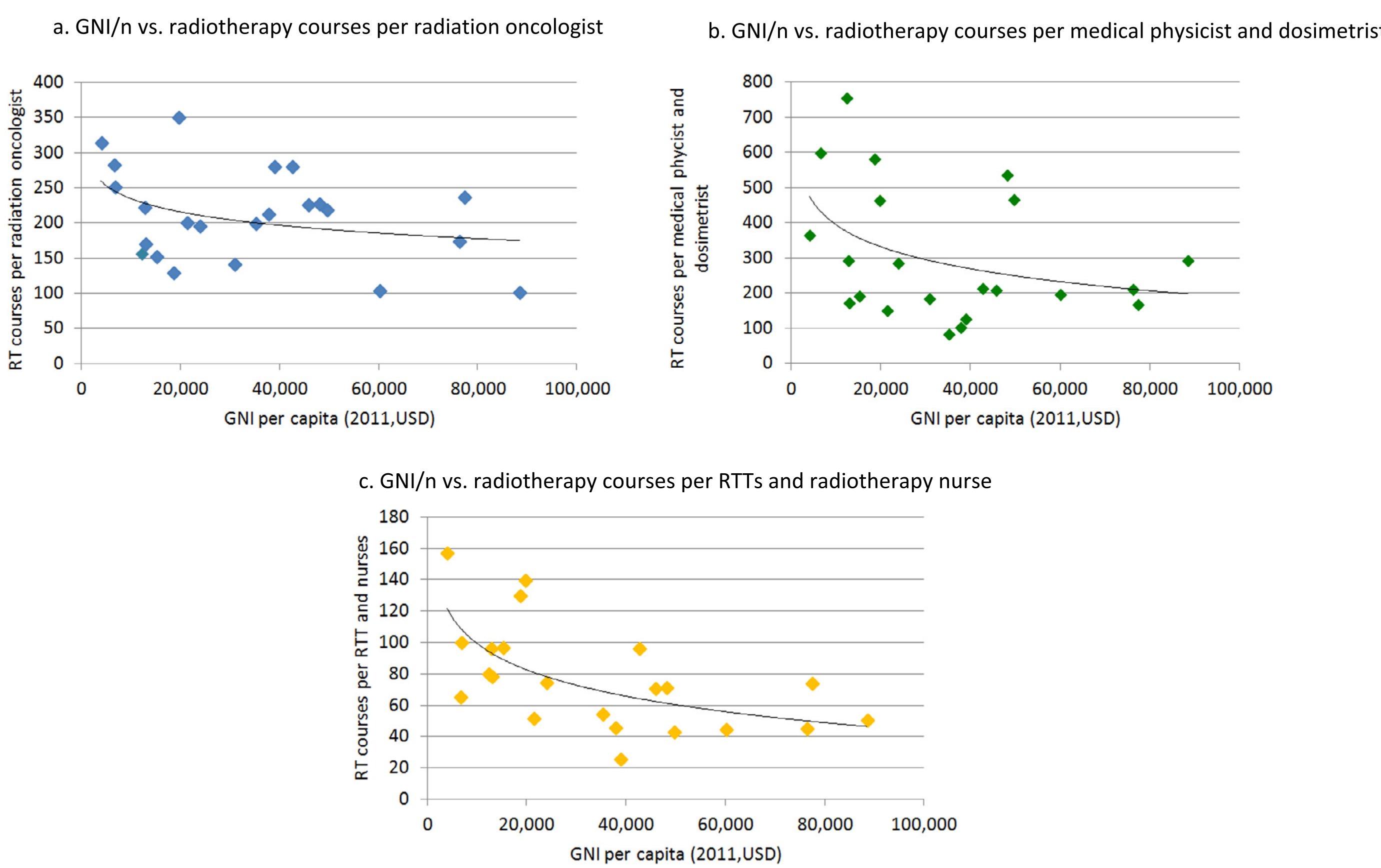


Fig. 3. GNI per capita (GNI/n) in relation to radiotherapy courses per different personnel categories.

Cluster analysis

The clustering analysis showed that the correlation coefficient of GNI to personnel per million inhabitants was $r = 0.5$ for RO, $r = 0.43$ for MP + DO and higher for RTT + RN ($r = 0.65$). Correlations among different personnel categories were low for RO and MP + D0 ($r = 0.13$) and almost identical for RO and MP + DO versus RTT + RN ($r = 0.44$ and $r = 0.43$ res.).

Average values for these variables in each cluster, identified using the k-means clustering analysis, are shown in Table 3. The

Table 3
Centroids of the clusters identified in the *k*-means clustering via principal components analysis.

	Cluster	GNI/n[a]	RO/n[b]	Mp + Do/n[b]	RTT + RN/n[b]
1	Albania, Belarus, Bulgaria, Estonia, Hungary, Lithuania, Montenegro, Poland, Malta	10.6	9.3	6.1	21.9
2	Czech Republic, Portugal, Slovenia, Spain	23.8	15.7	9.5	26.7
3	Austria, Belgium, France, Iceland, UK	41.9	11.3	15.2	39.5
4	Denmark, Ireland, The Netherlands	49.6	17.7	12.7	74.1
5	Luxembourg, Norway, Switzerland	80.7	17.2	11.6	46.8

[a] Per 1000.
[b] Units/million inhabitants.

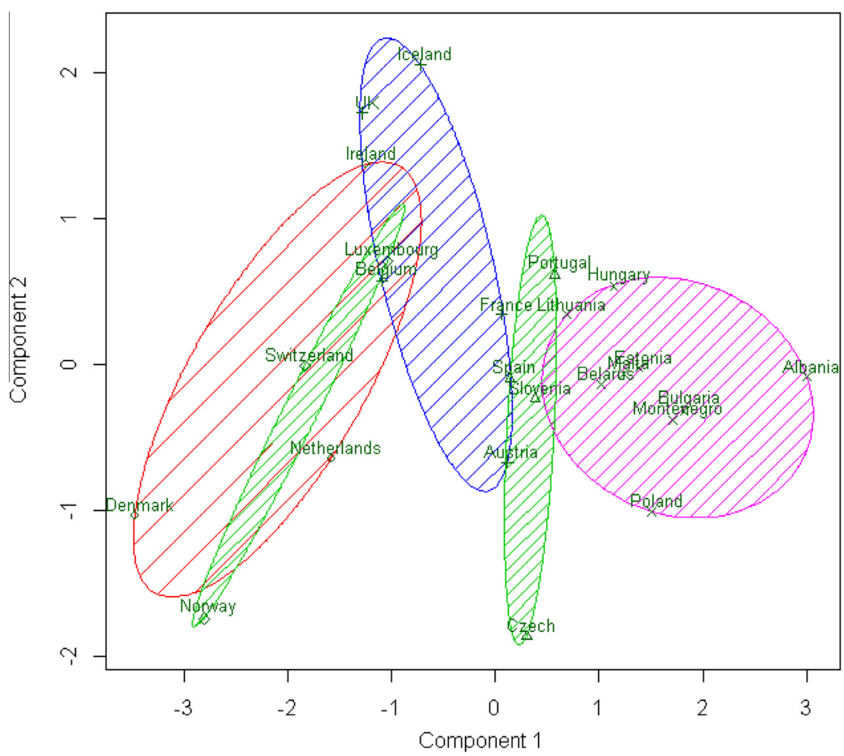


Fig. 4. Cluster analysis of the various countries based on GNI per capita versus personnel per million inhabitants.

four variables were graphically depicted using two axes. Using these two components, 5 clusters of countries are defined (Table 3 and Fig. 4), which explained 80.1% of the total variability.

Cluster 1 combines most Eastern European countries together with Malta. These countries show the lowest values of all variables considered in the analysis. Cluster 2 is predominantly made up of countries from Southern Europe (Portugal, Slovenia, Spain) along with the Czech Republic, all showing intermediate values for the variables considered. Although countries in clusters 3 and 4 have similar average GNI per capita, those in cluster 3 have lower staffing numbers, except for MP + DO, which are highest overall. It is remarkable, on the contrary, that countries in cluster 4 (Denmark, Ireland and The Netherlands) have the highest overall RTT + RN data. Cluster 5, finally, is constituted of countries with the highest GNI per capita and high numbers for RO per million (comparable to countries in cluster 4), but only average figures for MP + DO and RTT + RN.

Discussion

This paper presents the personnel data collected in the ESTRO HERO database, based on validated national data entry in collaboration with the National Societies. It demonstrates a large variability of all evaluated parameters.

Weighing personnel availability to population figures disregards cancer incidence and differences by tumour site distribution, both critical in determining optimal radiotherapy utilisation and hence the level of radiotherapy resources required [9,14]. It is therefore more relevant to relate staffing to a certain productivity level, such as courses or fractions delivered on an annual basis. But many European countries use both approaches in their guidelines: requirements for RTTs are frequently defined in relation to equipment numbers, in turn often determined by population figures, whereas national recommendations regarding radiation oncologists more frequently refer to patient loads [8,14]. Even so, our data show that both indices are inversely related (Table 2 and Figs. 2 and 3): countries with high staffing levels per million inhabitants typically treat fewer courses per staff per annum, regardless of the type of personnel and epidemiology, and vice versa.

Ten years ago, the QUARTS initiative proposed 1 radiation oncologist per 200–250 patients treated annually and 1 physicist per 450–500 patients. These guidelines were derived from the recommendations then in force in most European countries and were based on the actual situation, by no means reflecting the cancer incidence and population mix [15]. Similar figures are found across guidelines from other regions or regulatory agencies [16–20]. QUARTS did not make any firm recommendations regarding RTTs, because the available guidelines showed a large diversity and were mainly dependent on local habits, work distribution between the various disciplines and on treatment complexity [15]. In other groups, recommendations regarding RTTs were related to patient numbers, available equipment and/or operating hours [16–21].

Although our average figures for the European countries surveyed are consistent with the described recommendations, variations are substantial. Currently, radiation oncologists are responsible for an average of 208.9 courses per year. In 6 countries, however, the figure is still above or equal to 250, in contrast to 11 countries where the number has dropped below 200. Physicists are on average responsible for 356.0 courses annually, a number that goes down to 303.3 if dosimetrists are accounted for. The spread amongst countries is even larger than for radiation oncologists, with over 500 courses per year for physicists combined with dosimetrists in 4 countries, compared to 8 countries with numbers below 200. A large variation is also seen for the courses per professional responsible for treatment delivery, RTTs all or not combined with nurses, going from slightly above 25 in Ireland to more than 150 in Albania.

Apart from the large variability, our observations all point towards higher staffing levels and lower patient loads than recommended a decade ago by QUARTS. Radiotherapy techniques having evolved dramatically over the last decade, it is not surprising to observe lower patient numbers for all personnel categories in actual radiotherapy practice, as it reflects the increased time demands of the more complex treatment approaches (e.g., IGRT, adaptive radiotherapy) currently used [3–5]. In line with this, recommendations about numerical workloads have slightly reduced since the publication of QUARTS [8,15]. Guidelines follow practice, and the other way round. One striking example of how adapting recommendations can translate into higher staffing levels is found in Poland. New regulations issued by the Minister of Health, further endorsed by reimbursement per procedure by the National Health Fund together with investments in education and training, have resulted in increased staffing levels for all radiotherapy professionals [22].

A major obstacle to correcting staffing deficits is the long time scale required to educate additional personnel. Overestimating the needs may however also create difficulties with highly specialised staff unable to find work in the discipline for which they are qualified. Most studies indicate the greatest shortfall in RTTs but with the highest risk defined for radiation oncologists based on their age profile and longer education and training timeframe [23,24]. These issues underpin the need for accurate predictive models, several of which have already been published, for individual jurisdictions and focusing on the different personnel categories [24–27]. All these models point to the multitude of variables that must be considered when estimating staffing requirements with perhaps the most important being the increasing complexity and evolving fractionation schedules with related changing time demands.

It is well recognised that staff limitations in terms of quantity and quality jeopardize the delivery of state-of-the-art and safe radiotherapy [28,29] and restrict the potential of introducing new technologies such as IMRT, IGRT and SBRT [30–32]. A study in Japan revealed that the numbers of radiation oncologists and RTTs significantly correlated with the implementation of IMRT and those of radiation oncologists and physicists with the use of SBRT [31]. Kron et al. examined the evolution in physics staff between 2008 and 2011 in the Asia Pacific region and observed that the increase in physicists was just sufficient to compensate for the increase in linacs and in treatment complexity, leaving the profession in fact with the same personnel deficit [32].

Our data do not allow the definitive disentanglement of the impact of complexity, operational hours and professional roles and responsibilities, nor do they account for the involvement of various personnel groups in research and education.

In Europe, a wide variation is seen in working hours (5–6 h are still official in several countries), in annual holidays (ranging from 4 to 9 weeks per annum), in shifts per day on the linear accelerators (sometimes up to 3) and in the number of personnel per shift. As an example, in our review of radiotherapy guidelines, the recommendations for RTTs per treatment unit vary from 2 to 6 [8], probably reflecting the national culture and work regulations, the technology level and ensuing treatment complexity, the educational background and responsibilities of the staff.

In our view, this last factor should be specifically addressed in further staffing models. Our analysis was blurred by the fact that radiotherapy tasks are performed by different professional groups in many countries, and by extension, in various centres within each country (see also in the companion paper by Dunscombe et al. [8]).

Radiation oncologists administer chemotherapy in a large number of countries – Denmark, Norway, the United Kingdom, Estonia, the Czech Republic, only to name a few [8] – and may be responsible for first check-up and/or image verification, thus significantly increasing staff requirements [33]. Significant divergence exists in the responsibility for treatment planning and target volume and organs at risk delineation, with responsibility shared equally between RTTs, dosimetrists and/or physicists in high resource countries but with a predominance of the latter in low resource countries [8]. The latter is also supported by the low correlation between radiation oncologists and physicists and dosimetrists combined, suggesting different roles and criteria for resource planning by country.

The educational background of RTT staff is reflected in their daily activities and is in a transitional stage in several countries (Denmark, Spain and Belgium), translating into the variable RTTs/nurses ratios observed. RTTs are also routinely involved in activities not directly related to treatment delivery such as planning (amongst others in Ireland, Spain, The Netherlands, Austria, Norway, Denmark [8]), research and development (such as in Ireland and Denmark), patient information and support (e.g., in Ireland, Denmark, the United Kingdom), in administrative tasks (in Central and East Europe), in quality assurance and clinical education in many countries. It is worth mentioning, however, that in some countries (Denmark, Ireland and The Netherlands) these roles are translated in a higher ratio of RTTs per million inhabitants than in the rest of the countries, as shown by their inclusion in cluster 4, which is clearly defined by this variable.

Without a detailed background as to the roles and responsibilities it is challenging to compare the numbers of the different professionals involved in providing radiotherapy across the responding countries. For the same reason, it would also be advisable to account for these variations in predictive models for radiotherapy staffing, especially if they are to be applicable to a wide range of jurisdictions. The IAEA programme dealing with the development of a widely applicable staffing calculator addresses this problem by defining task groups (e.g., radiation oncology, medical physics, radiation therapy, etc.) rather than specific professional categories. This model also computes required staffing levels in FTEs, which are more appropriate than the personnel numbers that are still frequently in use in actual guidelines [34].

The former QUARTS analysis did not find clear correlations between personnel requirements and economic determinants of a country, possibly because wages are typically aligned with national prosperity [15]. In contrast, our data on available staffing resources do show that courses per year increase with decreasing

GNI per capita, especially for RTTs and nurses. As a consequence, in some of the European countries, the actual workload per staff is much higher than recommended and of the same order of magnitude as in African or Latin American countries, where socio-economic status is also typically lower [35–37]. Similar observations were made in the HERO equipment report, i.e., more courses delivered per megavoltage equipment and less advanced technology available with decreasing national wealth [7]. Hence, our findings on staffing may partly be a reflection of this lack of equipment and infrastructure, especially if personnel needs are defined on the basis of available equipment, as is often still the case for RTTs and nurses. Although the relation between staffing levels, equipment availability and national economic indicators may seem obvious, welfare is not the sole factor to explain the variability. The European cluster analysis shows how two clusters with comparable GNI/n have clearly distinct average personnel numbers. This finding clearly points to the relevance of health care decision making in terms of investment, tasks performed by each professional group and facility planning for radiotherapy beyond the relevance of GNI/n as an indicator of national welfare.

Our study encountered some limitations. Most nations do not have databases in which the requested data are readily available, and for many National Societies dedicated data collection was not possible within the constraints of their available resources. As a consequence, we were flexible in the year to which the data pertain, with the resulting mix in collection year as presented. In addition, evidence on courses delivered may have been obtained from different data sets, in turn translating into slightly different activity denominators.

The aim of this work was to benchmark among European countries. National averages however disregard regional variations within countries due to population density, accessibility of care, regional health care and reimbursement systems. Although beyond the scope of this work, future refinements at the regional level may be pursued.

Finally we acknowledge that some of the pragmatic decisions taken to allow analysis of this highly heterogeneous data set – the use of personnel numbers instead of FTE, grouping different personnel categories, the omission of trainees in the analyses – may have resulted in a simplification of reality.

In spite of these shortcomings, this is the most comprehensive data set on personnel resources in Europe available to date. We hope that the results of this experience will facilitate future updates of the HERO database and that the basis has been laid for an even stronger collegial network of National Societies. The next step in the HERO framework is to benchmark these data to the staffing needs in the individual countries, based on cancer incidence and stage mix and performed together with the Collaboration for Cancer Outcomes, Research and Evaluation (CCORE) in Australia [9,14]. We believe that providing such comparative data between needs and supply will strengthen European National Societies in their discussions with governments and financing parties and will help them to reduce any shortfall in radiotherapy staff. These data will further be used in the HERO costing model for European countries, which will allow comparing resource costs with reimbursement, providing budgetary estimates for radiotherapy optimisation in various jurisdictions and evaluating the value for money of novel radiotherapy treatments and technology.

In conclusion, the average personnel figures in Europe are now consistent with, or even more favourable than the QUARTS recommendations. This not only demonstrates that this type of research gives guidance for radiotherapy planning, but also reflects the steady evolution towards more technologically advanced and more accurate, yet also more time-demanding, treatment approaches. A considerable variation in available personnel and workload however persists among the highest and lowest staffing levels. This not only mirrors the variation in cancer incidence and socio-economic determinants, but also the stage in technology adoption along with treatment complexity, the different professional roles and responsibilities within each country, as well as the planning decisions made at the national level in the development and geographical spread of radiotherapy facilities. Our data underpin the need for accurate prediction models along with up-to-date guidelines and long-term education and training programmes.

Conflict of interest statement

The authors have no conflict of interest.

Funding sources

This project was supported by the European Society for Radiotherapy and Oncology.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.radonc.2014.08.034.

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