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Evaluation of radiotherapy education across the EU and the impact on graduates' competencies working on the linear accelerator

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A B S T R A C T

Introduction: Regulation and education of the professionals administering radiotherapy treatments in the linear accelerator varies across the EU. However, how different programme characteristics affect the level of competency of these professionals has never been studied before. This study also aimed to assess which are the least and most developed competencies in radiotherapy across the EU.
Methods: An online questionnaire was distributed to academic staff teaching radiotherapy across the EU. Staff were asked to identify the characteristics of the course programmes and to classify the level of competency of graduates regarding linear accelerator tasks.
Results: Fifty respondents from 19 EU countries answered the questionnaire. The least developed competency theme was *pharmacology* followed by *equipment quality assurance* and *management and leadership*. The most developed competency was *positioning and immobilisation*, followed by *radiotherapy treatment delivery* and *professional and ethical practice.* Some competencies are developed at the same level across EU countries, while others vary considerably between member-states. Longer programmes, with more placements, and larger proportions of radiotherapy in the programme showed significant increase in the development of some competencies. Longer placements in skills labs was correlated with a decrease in competency.
Conclusion: There is no harmonisation of radiotherapy eduction across the EU and the differences in programme characteristics are reflected in differences in competency levels of radiotherapy radiographers. This may hinder movement of professionals and create disparities in the level of care offered across the EU.
Implications for practice: Longer programmes, with longer clinical practice and adequate proportion of radiotherapy in the course are essential to ensure that these professionals are competent at similar levels across the EU and to ensure patient safety.

Introduction

The most common role of the therapeutic radiographer (TR) is the administration of Radiotherapy (RT) using a linear accelerator (linac). This is one of the most critical responsibilities of these professionals since errors have a significant impact on patient outcomes, resulting in a decrease in tumour control and an increase in patients' side-effects.[1,2]

However, roles and competencies of the TR vary across the EU[3] since neither the profession[4] nor the education is harmonised across Europe.[5–9] Although literature acknowledges the influence of course characteristics in competency level,[3] there is a gap in knowledge regarding the extent of this relationship.

The definition of "competency" varies across the literature.[10,11] Since the scope is to study these competencies in the EU context, the definition provided by the *Recommendation of the European Parliament and of the Council on the establishment of the European*

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Qualifications Framework (EQF) for lifelong learning[12] was used, which states that competency is the "ability to perform a task autonomously and take responsibility for it".

Having a good understanding of TRs' education in the EU is important because TRs can register to practise in any member-state if they comply with minimum requirements determined by the EC/2005/36 directive,[13] such as similar academic level and same "professional qualifications". However, the required "qualifications" to practise are not established in the same way across member states: only a few countries specify the necessary competencies for practice.[4] Therefore, recognition of qualifications is often based on the most fundamental characteristics of the courses such as academic level, duration of the programmes or which specialisms the graduate covered in the programme. Since, in most countries, competencies are not a criterion used to assess if the TR meets the requisites to practise,[4] TRs may be able to move within the EU even though they may not have developed the same competencies. This discrepancy led the researchers to analyse if courses that seem similar (for instance, with the same academic level and specialisms) are also identical in other course characteristics and competencies.

Multiple international reference documents[14–17] are used in the design of education programmes to train RT professionals, however, the implementation of these guidelines and their impact on the competency level of the graduates has never been published. Another study[18] performed a thematic analysis of relevant literature to create a list of the TR competencies applicable to the linac, yet, the study did not specify at what level graduates across the EU develop these competencies. In the current study, the term "graduate" refers to a person who successfully completes a course programme, irrespective of the academic level.

Given all the knowledge gaps identified above, this study aimed to assess the relationship between the characteristics of education programmes across the EU and competencies developed by the graduate TR working in the linear accelerator. The following objectives were defined: i) describe the characteristics of RT education programmes across the EU, ii) identify the level of development of linear accelerator competencies in European education programmes; iii) evaluate the effect of course characteristics on the competency levels developed.

Understanding the characteristics of RT education programmes and identifying which features most influence the competency levels, allows decision-makers to use evidence when designing the education programmes. This will also enable education institutions to improve their programmes, ultimately resulting in improved care to RT patients. It is also critical to identify which competencies are less developed between countries to close these gaps and subsequently, facilitate movement of TRs across Europe and improve patient care.

This study was developed as part of the SAFE EUROPE project aiming to study the education and movement of TRs in the EU. This European-funded research project included partners from different backgrounds (education institutions, professional organisations and an oncology hospital) from four countries (Malta, Poland, Portugal, the United Kingdom) and a European-wide professional organisation.

Methods

A quantitative cross-sectional study using an anonymous online questionnaire was deemed appropriate to achieve the aims of this study.[19–22] The questionnaire was distributed to academic staff teaching RT across the EU.

Due to the lack of a database of RT education programmes, extensive sampling and probabilistic sampling was not possible. Convenience sampling was undertaken using multiple strategies to maximise the dissemination of the study. The SAFE EUROPE project partners[23] distributed the questionnaire through email to their members, through social media and on the consortium's webpage between April and September 2019.

Questionnaire design

The first part of the survey inquired about the characteristics of the education programmes (Table 1). Closed-ended questions were designed for ease of data analysis; however, an option to submit "other" answers was available in all relevant questions and respondents could provide additional comments in every section of the questionnaire.

In the second part, the respondents were asked to score how competent graduates are at the end of the programme. They were invited to rate 63 competencies related to the linac, organised under 14 competency dimensions[18] (Table 1). The selection of the competencies was based on an analysis of the literature, results from previous research performed by this research team[18] and feedback from expert partners within the SAFE EUROPE project.

The respondents were asked to classify each competency between 1 (competency not developed in the programme) and 7 (competent) based on their experience and perception. Respondents were also provided with the definition of competency described above.

Three experts in RT education were invited to assess the content validity of the questionnaire. They were asked to classify each item (scale from 1 to 4) with regards to their relevance to the study aims. An Item Content Validity Index (I-CVI) of 1 was obtained for all items on the questionnaire showing that the experts agree that the items were relevant to the study aims.[24–28]

For the classification of the competency level, a 7-point Likert scale was chosen as it provides a more refined scale to measure the intensity of a rating evaluation when compared with a 5-point scale.[29–31] Four academic staff from two higher-education institutions were asked to answer the questionnaire, and the Inter-Class Correlation (ICC) was calculated using a two-way random, single rater and absolute agreement model. This test assessed if one member of academic staff would reliably represent the perception across one institution and if the answers of these raters could be generalised to the entire population (European academics).[32] ICCs of .788 ($p < 0.001$) and .536 ($p < 0.001$), and a Cronbach's alpha coefficients of .880 and .706 were achieved, for each institution.[32] These tests showed that there was a slight variation between respondents from the same institution when rating the competency levels. However, these values reflect a moderate to good inter-rater reliability.[32,33] Also, having multiple respondents from the same country further minimises the impact of subjective perception by the respondents.[34,35]

Statistical analysis of the data

The following hypotheses were tested using different statistical tests. Friedman's test was used to compare competency levels between dimensions (the Wilcoxon signed-rank tests with Bonferroni correction was conducted as a *post hoc* test). The Kruskal–Wallis tests were used to compare competency levels between groups with different course characteristics (the Dunn's test with Bonferroni correction was used as a *post hoc* test). The Spearman's rank correlation test was used to measure the strength of the relationship between course characteristics and competency scores. For all statistical tests, a .05 level of significance level was adopted.

Table 1
Variables studied in this research project.

Course Characteristics	Competency dimensions
Academic level	1 Radiation safety
Specialisms	2 File verification
Duration of the programme	3 Positioning and immobilisation
Duration of placement (all specialisms)	4 Radiotherapy treatment delivery
Duration of RT-specific placement	5 Image verification of patient setup
Proportion of course dedicated to RT	6 Equipment quality assurance
Proportion of placement dedicated to RT	7 Professional and ethical practice
Proportion of RT placement in skill labs	8 Patient care
Guidelines used in the design of the course	9 Pharmacology
Regulation of learning outcomes	10 Research and education
Requirement of registration to practice	11 Quality and risk management
	12 Management and leadership
	13 Decision making
	14 Teamwork and multidisciplinarity

Ethical considerations

Ethical permission for the study was granted by the Institute of Nursing and Health Research Ethics Committee at Ulster University, Belfast. A participant information sheet was provided. Neither the participant's name nor the institution was asked in the questionnaire, ensuring anonymity, and data was stored in password-protected or locked places. To avoid coercion, recruitment was performed by the SAFE EUROPE partners and social media. No harm was caused to the participants nor researchers.

Results

A total of 73 responses were obtained. Twenty-three responses were excluded because they were from non-EU countries, did not include RT in their course, or the respondents were not RT lecturers or head-of-department in the education programmes. Therefore, a total of 50 valid responses were analysed, representing 19 EU member-states. Some respondents identified different course structures inside the same country (Table 2). These programmes with different structures allow graduates to practise RT but have different academic levels, specialisms or programme duration. Since the UK was an EU member-state at the time of the data collection, it was included in the data analysis.

Table 2
Total respondents by country.

Country	Number of respondents
Austria	1
Belgium	1
Denmark	1
Estonia	1
Finland	1
France	1
Germany	3
Greece	1
Italy[a]	3
Latvia[a]	2
Lithuania[a]	2
Malta	2
The Netherlands[a]	5
Poland[b]	10
Portugal	6
Slovakia	1
Slovenia	2
Sweden	1
United Kingdom	7
TOTAL	50 respondents 19 countries 25 course structures

[a] Two different course structures.
[b] three different course structures.

Characteristics of radiotherapy education programmes across EU countries

Based on the responding countries, a picture of the education characteristics across the EU is presented here. For countries with more than one programme structure, these were analysed independently since the respondents referred to these programmes separately, resulting in a total of 25 entries (Table 2).

Main characteristics: academic level, specialisms and programme duration

The majority of programmes are bachelor's degrees (EQF6) (Fig. 1), most of which are dual-qualification programmes (imaging and radiotherapy). A minority of countries identified the existence of RT-only programmes (UK and Italy). Portugal recognised that the programme changed from RT-only to dual-qualification in 2014. Italian respondents identified the presence of both dual-qualification and RT-only programmes. While in two countries, the bachelor's degree includes radiotherapy, imaging and electrophysiology (France and Poland).

Only two programmes were identified as having an EQF level lower than 6: Germany has a dual-qualification programme at EQF4, and Poland offers a programme in radiotherapy, imaging and electrophysiology at EQF5.

Regarding postgraduation programmes, one RT-only programme with the duration of a single semester was identified in Sweden. This course was identified as suitable for nurses or diagnostic radiographers. Poland has a 2-year dual-qualification MSc, which allows graduates to practise RT. However, some Polish respondents identified that a total of 5 years are required to practise, which includes a BSc followed by an MSc (represented as "EQF 6 + 7" in the graphs).

Most EQF6 courses have a 3-year duration. However, programmes with 3.5-year or 4-year duration exist (Fig. 2). Although the course duration seems different between academic levels, a statistical difference was not observed ($H(2) = 3.393$, $p = 0.183$). The most prolonged programme duration corresponds to the Polish model of BSc followed by MSc; the shortest term refers to the Swedish postgraduation course.

Duration of clinical placement (including all specialisms)

Across the responding countries, the average placement duration (including all specialisms) was 1179 h (SD = 721.8). Regarding EQF6 programmes, the average is 1200 h of clinical placement (SD = 757.9). RT-only programmes have a lower average of clinical placement duration (845 h), followed by dual-qualification programmes (1186 h). Programmes that have more specialisms include longer placement duration (2100 h) (Fig. 3). Despite the difference in mean placement duration between RT-only programmes and those with other specialisms, this was not statistically significant ($H(2) = .442$, $p = 0.506$).

The EQF4 programme has a longer duration of clinical placement (1645 h) than the average of the bachelor's degrees (1200 h) while the clinical placement in the EQF5 programme was the shortest of all academic levels (450 h). Although the "EQF 6 + 7" programme corresponds to a total of 5 years, it has 1106 h of clinical placement which is shorter than the bachelor's degrees. The

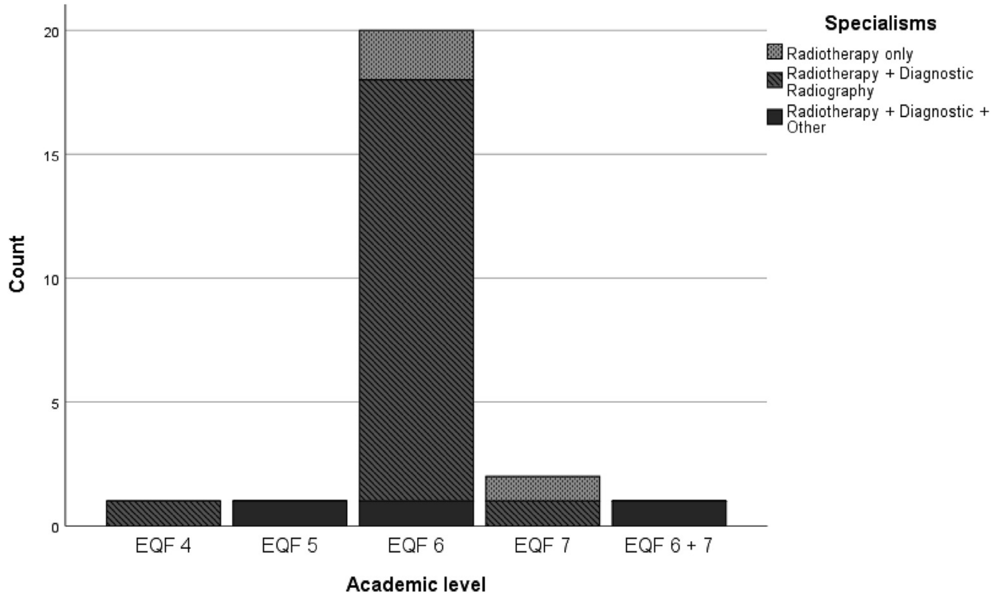

Figure 1. Academic level and specialisms included in the education programmes in RT across European countries.

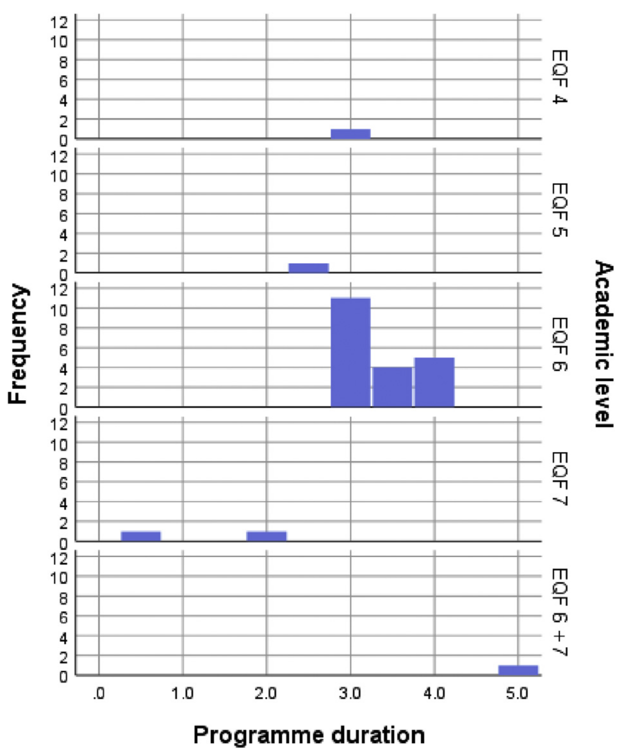

Figure 2. Duration of course programmes (according to academic level).

duration of clinical placement was not statistically different between academic levels (H(2) = .058, p = 0.972).

Proportion of course dedicated to radiotherapy

The average percentage of the programme devoted to radiotherapy subjects across the responding countries is 31%. As expected, RT-only programmes have a very high proportion of the programme dedicated to RT with an average of 88% of the programme dedicated to this specialism (Fig. 4). However, in courses that include other specialisms, the amount of the programme devoted to RT drops considerably (average of 25%). The average workload dedicated to RT is statistically higher in RT-only programmes when compared with programmes that include other specialisms (H(1) = 7.935, p = 0.005).

Regarding dual-qualification courses at EQF6 level, the average percentage of RT in the programme is only 24%. In one country, the proportion of workload was less than 10% even though the course allows the graduate to practise RT. On the other hand, some dual-qualification courses can have up to 60% of the programme dedicated to RT. No statistical difference was found between countries with different academic levels (H(2) = 2.202, p = 0.333).

Proportion of clinical placement in radiotherapy

RT-only programmes have a high proportion of clinical placement dedicated to this specialism, with an average of 94% of the placement in this specialism (Fig. 5).

Dual-qualification programmes (radiotherapy and imaging) tend to dedicate a higher proportion of the clinical placement to imaging. On average, courses with other specialisms besides RT, only devote 27% of the clinical placement to RT. The mean proportion of the placement in RT is statistically higher in RT-only courses than courses that include other specialisms (H(1) = 8.052, p = 0.005).

Although the majority of the dual-qualification EQF6 programmes (11 out of 17) have a proportion of RT placement lower than 30%, there are a few courses with higher percentages of placement dedicated to RT. One of these dual-qualification courses has more than 70% of clinical placement dedicated to RT.

Duration of the clinical placement in radiotherapy

The respondents provided data regarding the total number of clinical hours and the proportion of this time that is dedicated to RT. From this data, the researchers computed the number of hours in RT placements (Fig. 6). The average number of hours was of 459 h (SD = 532.9)

RT-only courses have the highest average RT clinical practice hours (771 h). Dual-qualification courses have a shorter RT placement duration (439 h) with most of the dual-qualification programmes (7 out of 13) having less than 250 h of placement in RT. Nevertheless, dual-qualification programmes can have as high as

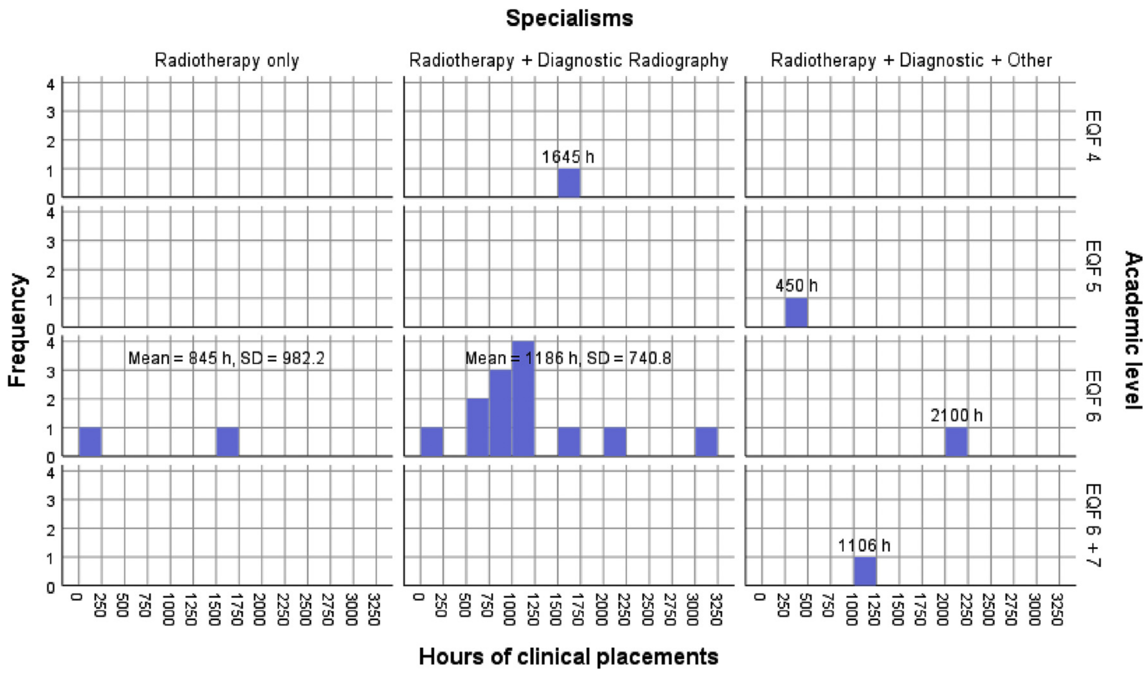

Figure 3. Duration of clinical placement in all specialisms (in hours) (according to academic level and specialisms).

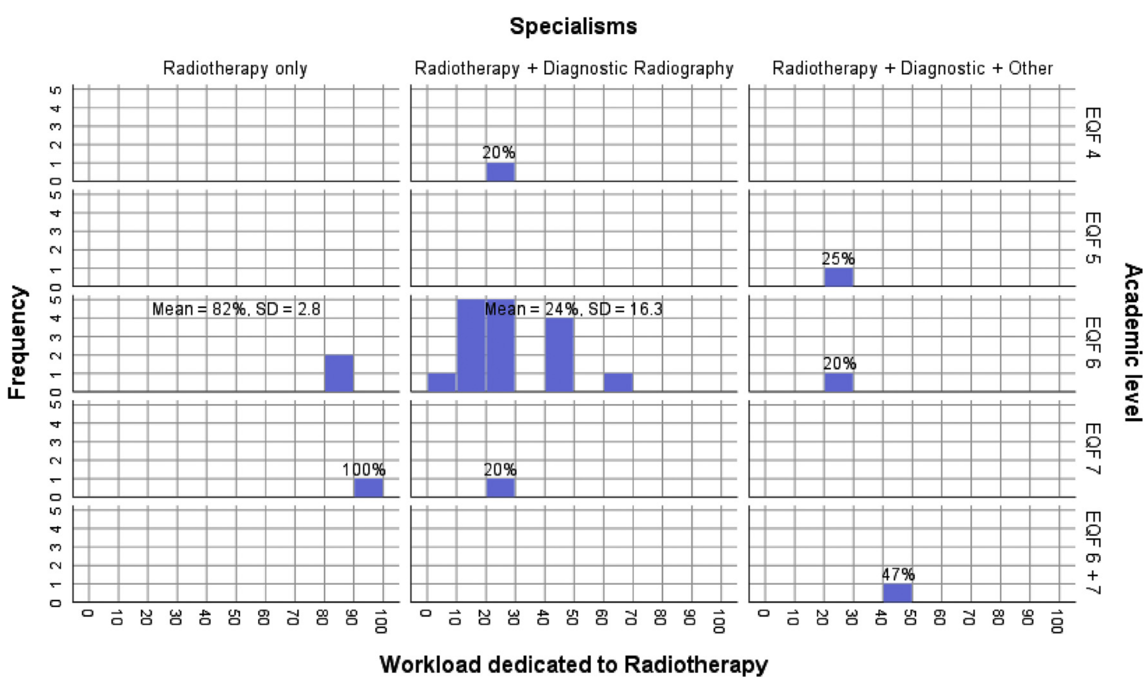

Figure 4. Proportion of the programme dedicated to RT (according to academic level and specialisms).

2114 h of clinical placement in RT. No statistical significance was found between RT-only courses and course with other specialisms (H(1) = .217, p = 0.642).

Proportion of radiotherapy placement delivered in skill labs

In average, 233 h (SD = 254 h) or 18% (SD = 16.2%) of the clinical placement is delivered using skill labs. Although the tendency is to have a low proportion of training in skills labs, this proportion can be as high as 890 h or 60% of the clinical placement hours. The percentage of clinical training in skill labs is similar across the course programmes (Fig. 7). No statistical differences were found between RT-only courses and course with other specialisms (H(1) = .158, p = 0.691).

Regulation of learning outcomes at the national level

In most countries, the learning outcomes are defined by law or regulation (11 out of 16). Regarding registration, this was mandatory in 12 countries, not available in two countries, and optional in two others. Three countries did not reply to these questions.

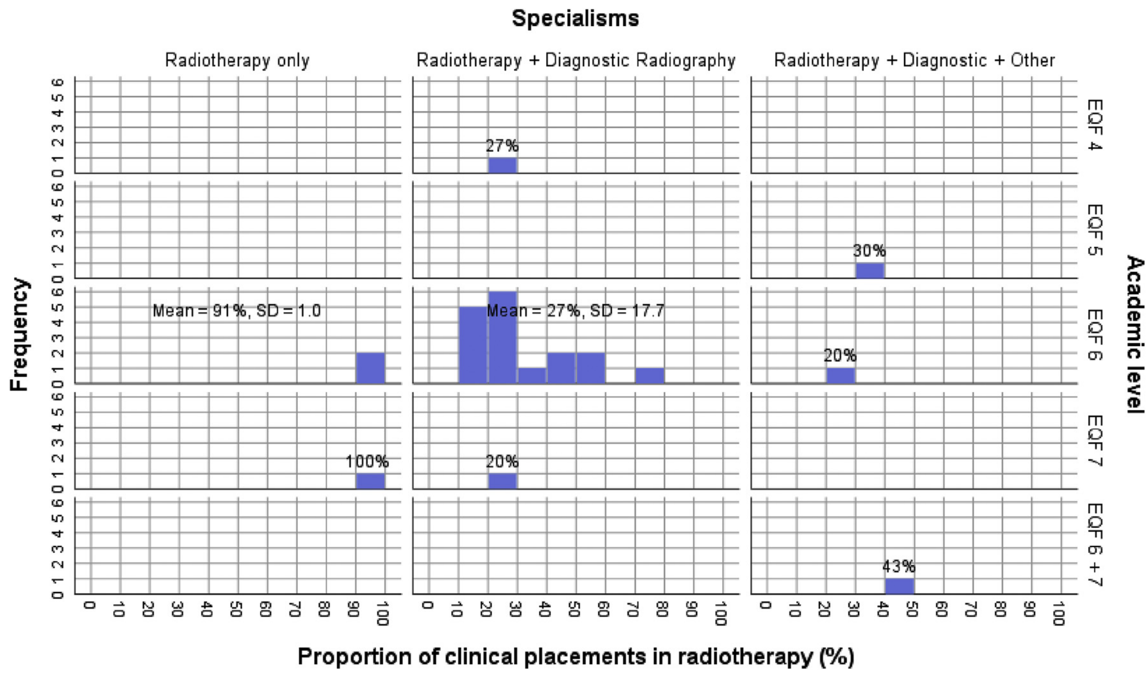

Figure 5. Proportion of clinical placement in RT (according to academic level and specialisms).

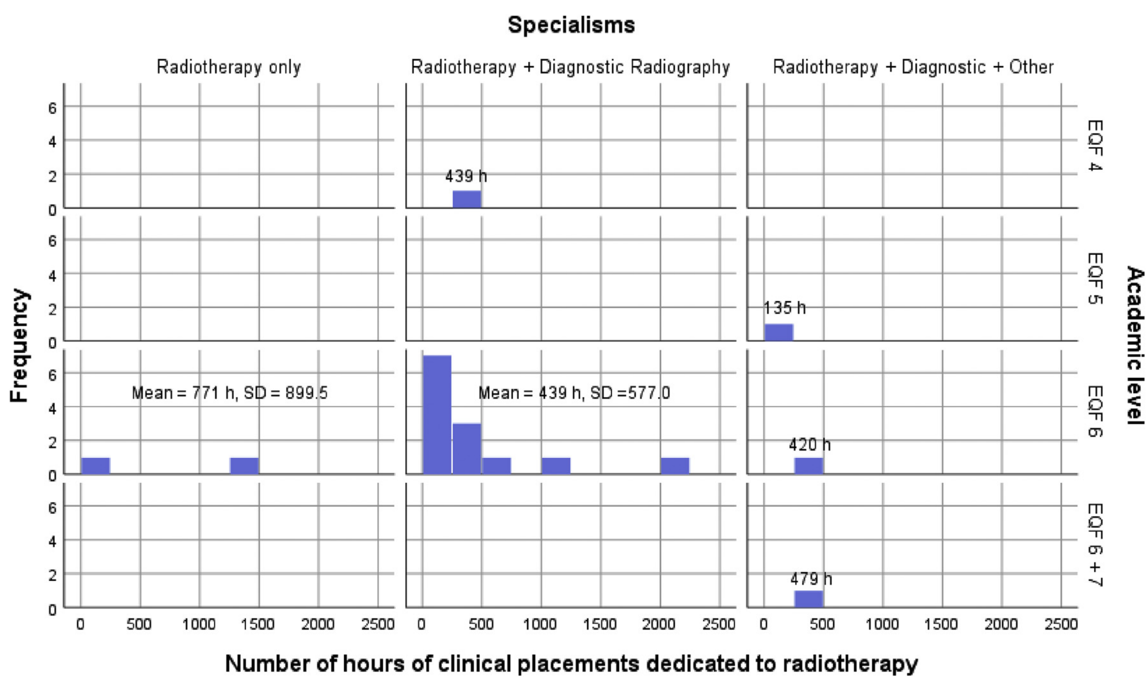

Figure 6. Duration of clinical placement in RT (in hours) (according to academic level and specialisms).

Least and most developed competencies across the EU

The Friedman test ($X^2(13) = 131.86$, $p < 0.001$) demonstrated that some competencies are less developed than others (Fig. 8). The pairwise comparisons showed that *Pharmacology, Equipment quality assurance, Research and education,* and *Management and leadership* are significantly less developed than *Teamwork and multidisciplinarity, Professional and ethical practice, Radiotherapy treatment delivery* and *Positioning and immobilisation* ($p < .05$). Fig. 8 also shows discrepancies in the level of development of the different competency dimensions across the EU.

Comparison and correlation of competency level with course characteristics across the EU

The replies from the 50 respondents were used to analyse the effect of programme characteristics on the level of the competency

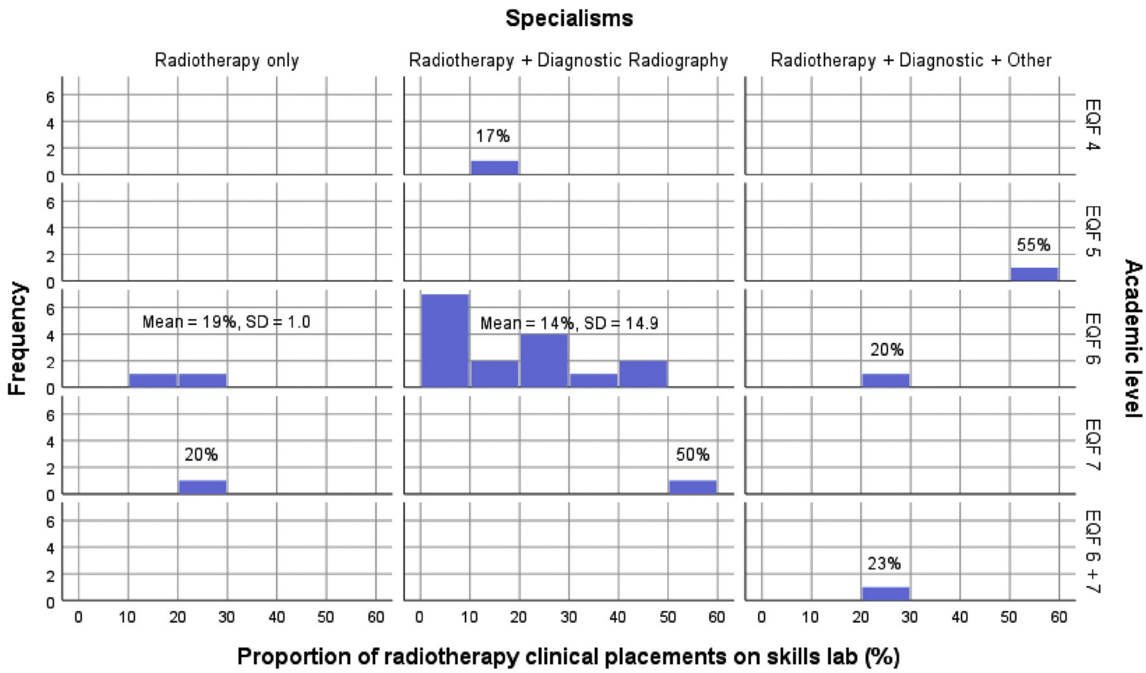

Figure 7. Proportion of RT placement delivered on skill labs (according to academic level and specialisms).

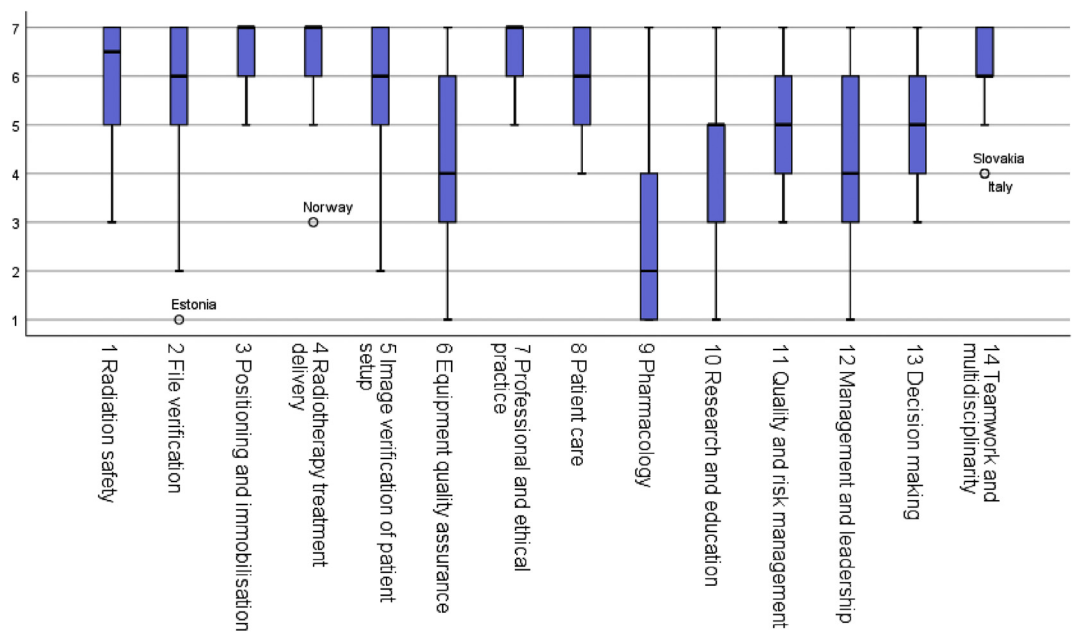

Figure 8. Distribution of the competency scores across EU member states.

dimensions. The results of the comparison and correlation tests are shown below.

Academic level and specialisms

The competency level was compared between i) courses with academic level below EQF6, ii) courses at EQF6 and iii) courses higher than EQF6. The groups showed statistically different levels of competency regarding *Quality and risk management* ($H(2) = 6.043$, $p = 0.049$). The *post hoc* test showed that courses below EQF6 have a significantly lower competency level (mean = 3.778) when compared with courses above EQF6 (mean = 6.056) ($z = -21.167$, $p = 0.042$). The groups did not show significant differences in any other competency dimension.

The specialisms included in the programme seem to be associated with significantly different competency levels regarding *File verification* ($H(2) = 6.057$, $p = 0.048$) and *Equipment quality assurance* ($H(2) = 6.764$, $p = 0.034$). RT-only programmes (mean = 5.889) developed higher *Equipment quality assurance* competency than dual-qualification programmes (mean = 3.965) ($Z = 13.194$, $p = 0.044$). The pairwise comparisons showed no significance for the *File verification* dimension.

Duration of programme and placement (all specialisms)

The duration of the course programme and placement were correlated with an increase in some competency scores (significant results highlighted in Table 3). Figs. 9 and 10 show the relationship between these course characteristics and the competency dimensions that have a significant correlation: a linear fit line was plotted to better understand the relationship between the programme characteristic and the competency level.

Proportion of the programme and placement dedicated to radiotherapy

The proportion of the course and placement dedicated to RT seems to correlate with an increase in several competency dimensions (significant correlations were highlighted in Table 3). Figs. 11–13 illustrate the correlation between these characteristics and the competency scores.

From the data collected, it seems that the proportion of RT clinical placement delivered in skills labs correlates negatively with competency scores in *Pharmacology* ($r = -.300$, $p = 0.045$). The correlation between these variables can be seen in Fig. 14.

Regulation and design of learning objectives

Registration to practise seems to affect various competency dimensions significantly. Table 4 shows the mean scores according to the registration process. Post hoc tests were run, and the pairwise comparison of the groups showed that courses from countries where there is no registration have lower competency levels regarding *Positioning and immobilisation, Radiotherapy treatment delivery, Image verification of patient setup, Equipment quality assurance, Professional and ethical practice, Research and education, Quality and risk management, Management and leadership* and *Teamwork and multidisciplinarity* when compared with mandatory registration, optional or both ($p < 0.05$). In addition, mandatory registration showed higher *Pharmacology* competency levels when compared with programmes in countries with optional registration ($Z = 16.081$, $p = 0.006$).

Thirty-eight programmes included competencies in their learning objectives, while ten of the respondents stated that the learning objectives do not include competencies. Nevertheless, it seems that including the competencies in the learning objectives does not affect the competency level perceived by the respondents ($p > 0.05$). Programmes from countries where the learning outcomes are defined by the national regulation ($n = 34$) also did not

Table 3
Correlation between course characteristics and the competency score (significant results highlighted).

		Programme duration	Duration of clinical placement	Proportion of programme dedicated to RT	Proportion of clinical placement dedicated to RT	Duration of clinical placement dedicated to RT	Proportion of RT clinical placement on skills lab
1 Radiation safetyrowhead	r_s	−.010	.392	.485	.444	.434	.170
	p	.948	.017	.000	.001	.007	.249
	N	49	37	49	50	37	48
2 File verificationrowhead	r_s	.070	.414	.544	.489	.564	.112
	p	.635	.012	.000	.000	.000	.453
	N	48	36	48	49	36	47
3 Positioning and immobilisationrowhead	r_s	−.035	.235	.435	.474	.353	.058
	p	.811	.161	.002	.001	.032	.696
	N	49	37	49	50	37	48
4 Radiotherapy treatment deliveryrowhead	r_s	.053	.402	.565	.569	.552	.062
	p	.719	.015	.000	.000	.000	.678
	N	48	36	48	49	36	47
5 Image verification of patient setuprowhead	r_s	.198	.370	.011	.074	.268	−.091
	p	.173	.024	.941	.608	.109	.539
	N	49	37	49	50	37	48
6 Equipment quality assurancerowhead	r_s	−.021	.326	.538	.487	.474	.263
	p	.887	.049	.000	.000	.003	.071
	N	49	37	49	50	37	48
7 Professional and ethical practicerowhead	r_s	.113	.264	.425	.457	.476	−.073
	p	.446	.115	.003	.001	.003	.625
	N	48	37	48	49	37	47
8 Patient carerowhead	r_s	.017	.231	.378	.364	.322	.007
	p	.907	.169	.007	.010	.052	.961
	N	48	37	49	49	37	47
9 Pharmacologyrowhead	r_s	−.092	.048	.107	.114	.095	−.300
	p	.542	.785	.472	.447	.586	.045
	N	46	35	47	47	35	45
10 Research and educationrowhead	r_s	.327	.098	.119	.163	.244	.017
	p	.023	.563	.414	.262	.145	.911
	N	48	37	49	49	37	47
11 Quality and risk managementrowhead	r_s	.292	.071	.246	.251	.229	.062
	p	.044	.677	.089	.082	.174	.679
	N	48	37	49	49	37	47
12 Management and leadershiprowhead	r_s	.299	−.124	.080	.111	−.029	.139
	p	.039	.466	.583	.450	.863	.352
	N	48	37	49	49	37	47
13 Decision makingrowhead	r_s	.374	.071	.154	.212	.166	.053
	p	.010	.680	.295	.147	.333	.727
	N	47	36	48	48	36	46
14 Teamwork and multidisciplinarityrowhead	r_s	.166	.118	.153	.246	.246	.036
	p	.259	.485	.294	.088	.142	.812
	N	48	37	49	49	37	47

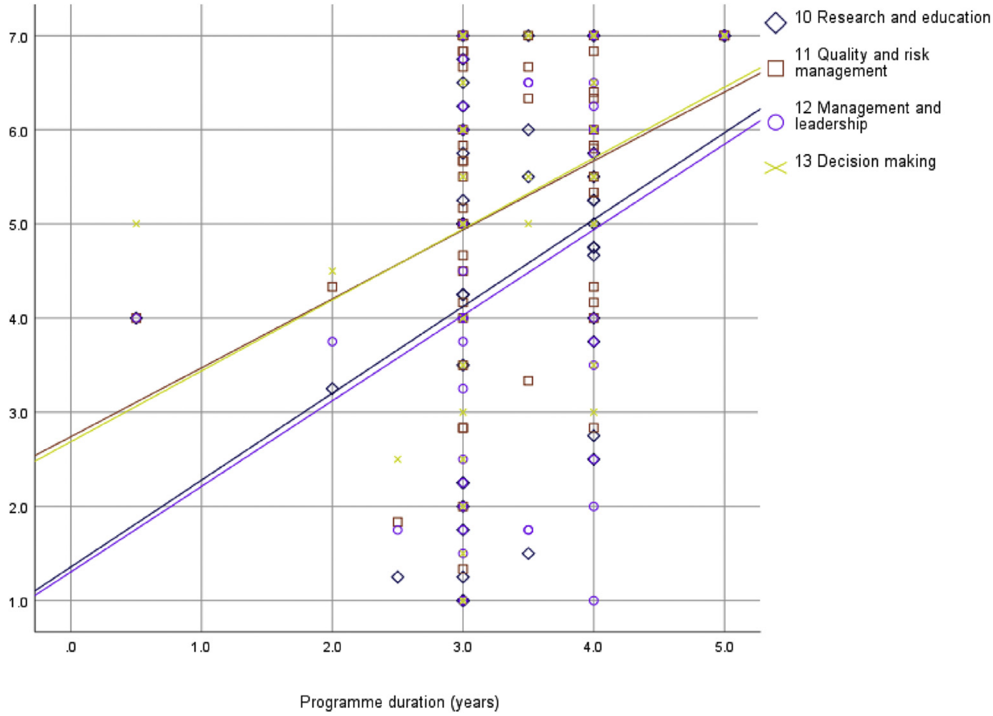

Figure 9. Bivariate scatter plot of programme duration (in years) with competency scores that showed significant correlations. The linear fit line is also shown.

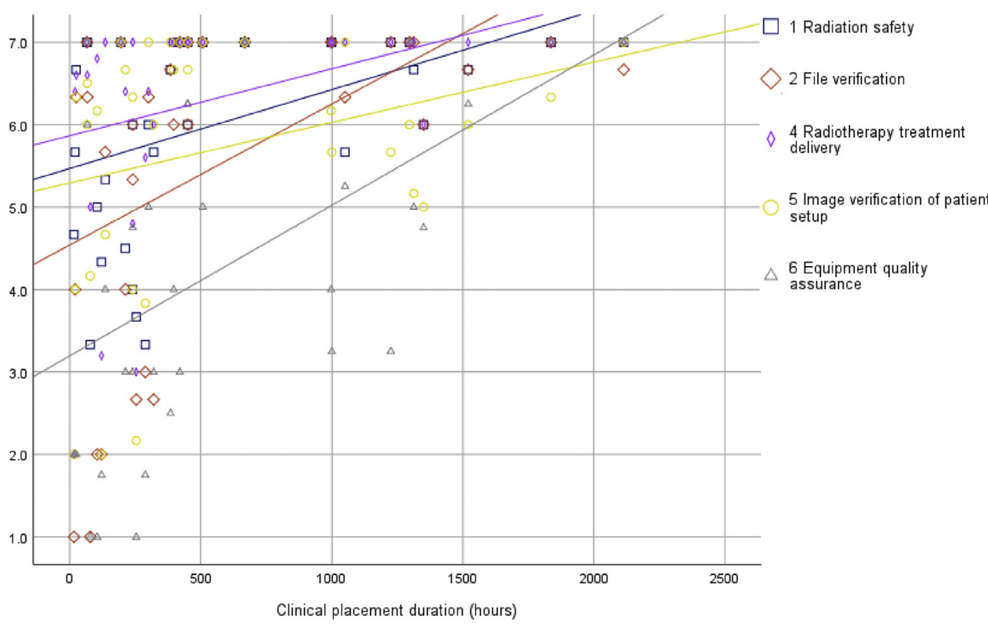

Figure 10. Bivariate scatter plot of Placement duration (in hours) with competency scores that showed significant correlation. The linear fit line is also shown.

show any significant difference from those who do not (n = 13) ($p > 0.05$).

Regarding which guidelines are followed in the course design, most respondents stated that they followed at least one international guideline (24 out of 36) and from these, most programmes follow the European Federation of Radiographer Societies (EFRS) (n = 18) and the European SocieTy for Radiotherapy and Oncology (ESTRO) guidelines (n = 14).

Programmes that use at least one international guideline showed significantly higher levels of development for some competency dimensions (Table 5). Further analysis was performed to assess how the use of each of the documents mentioned in the questionnaire[14–17] relate to competency level. It was observed that courses that use EFRS[14] and ESTRO[15] reference documents have higher levels of development for certain competency dimensions (Table 6). The use of IAEA[16] or HENRE[17]

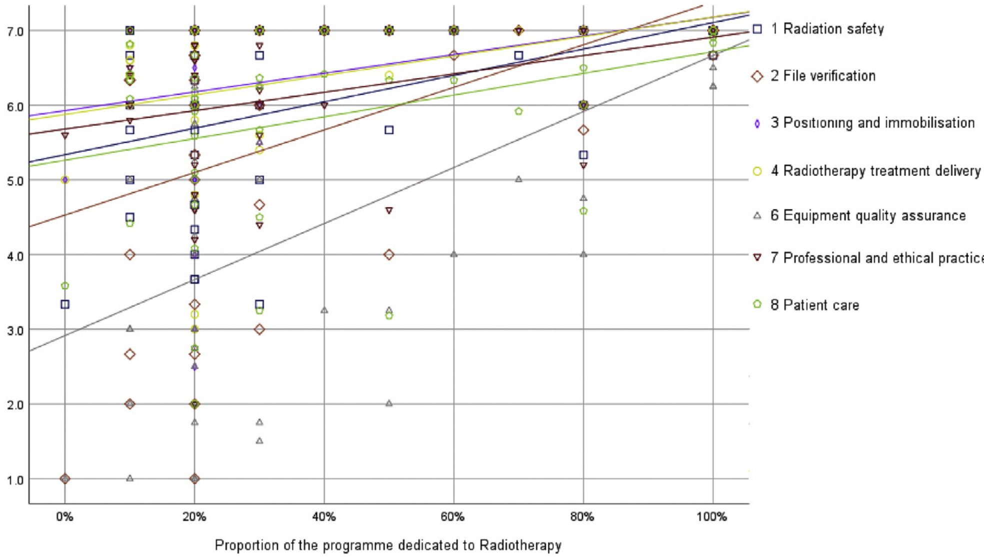

Figure 11. Bivariate scatter plot of the proportion of curriculum dedicated to RT with competency scores that showed statistically significant correlation. The linear fit line is also shown.

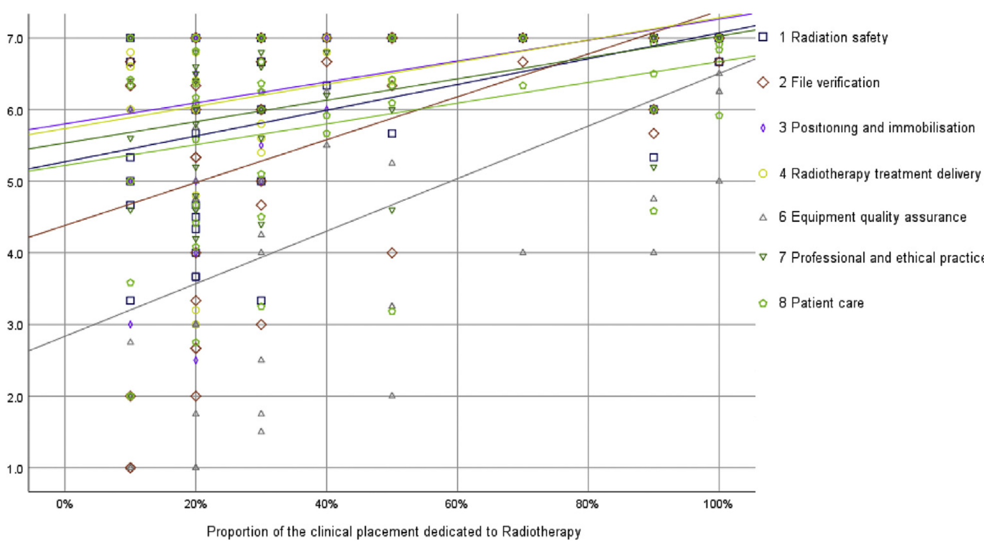

Figure 12. Bivariate scatter plot of the proportion of clinical placement dedicated to RT with competency scores that showed statistically significant correlation. The linear fit line is also shown.

recommendations did not significantly influence the competencies scores ($p > 0.05$).

Discussion

Uniformity of radiotherapy education in the EU (or lack thereof)

Some level of harmonisation can be observed since the majority of countries seem to offer dual-qualification programmes at EQF level 6 with a duration between 3 and 4 years, corroborating previous studies.[6,7,36] These similarities facilitate movement between EUcountries since these are the characteristics most often verified before granting recognition of qualifications abroad.[4,13] However, not all member-states offer programmes with these characteristics: the programmes vary between 1 semester and 5 years in duration; EQF level between 4 and 7; and programmes can be either dedicated to radiotherapy; dual-qualifications (imaging and radiotherapy); or even include additional specialisms (such as electrophysiology).

In addition, programmes which, at face value, may seem similar (same academic level, programme duration and specialisms) presented considerable variation in terms of duration of clinical placement, the proportion of the programme and of clinical placement dedicated to RT, duration of RT-specific placement and the use of skill labs. As such, an appropriate comparison of programmes (such as for the recognition of qualifications abroad) must include the assessment of more than just the academic level, duration and specialisms. Even though some countries have a very comprehensive process of verifying foreign graduates' applications, with an extensive list of criteria for registration, this does not

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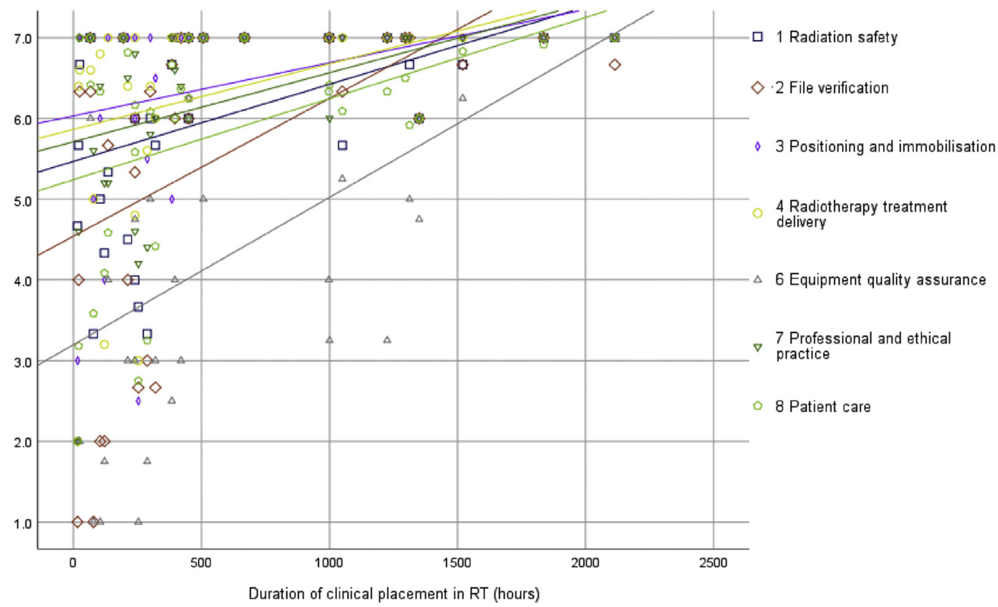

Figure 13. Bivariate scatter plot of the duration of RT placement with competency scores that showed statistically significant correlation. The linear fit line is also shown.

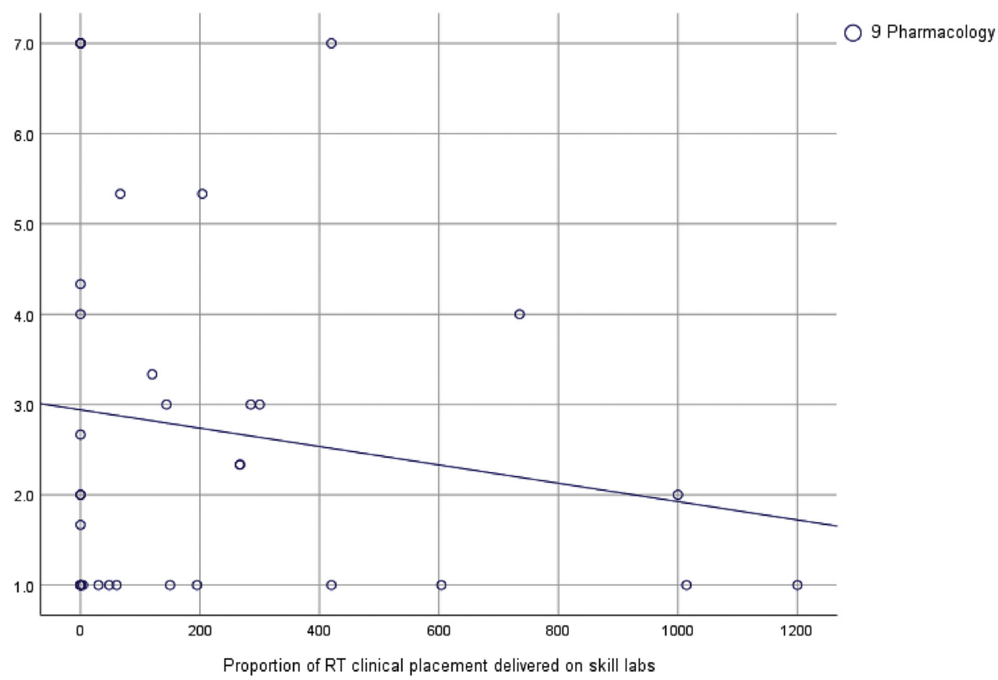

Figure 14. Bivariate scatter plot of the proportion of RT placement delivered in skills labs with Pharmacology competency scores. The linear fit line is also shown.

happen in all EU countries[4]; therefore, the competencies developed may not match those practised in the destination country.

The lack of homogeneity was also evident in terms of the competency level. Even though some competency dimensions seem to be well developed across member-states, in other dimensions, the competency can be fully developed in one country and not developed at all in others. Even though this disparity is more evident in non-technical competencies (such as *Management and leadership*), it was also observed in technical competencies (such as *Equipment quality assurance* and *Image verification of patient setup*). These results showed that some competencies identified in the literature as being the responsibility of the TRs[18] are not fully developed across the EU. As such, these disparities have the potential to become an issue when movement occurs, and further research should be performed.

Harmonisation of education would ensure that graduates are prepared to practise the profession safely and competently in any other country. EU member states may benefit of harmonisation in education in many ways: professionals can move from countries with a surplus of TRs to countries with lack of these professionals; the same level of care may be offered to patients irrespective of the country; sharing of educational resources between countries; faster evaluation of foreign applications for registration in the profession; patient safety when TRs move to a different member state, amongst others.

Table 4
Mean competency score according to the country's registration process (significant results highlighted in bold).

	There is no registration at national level (n = 7)	Registration at national level is mandatory (n = 33)	Registration is optional (n = 7)	Kruskal Wallis
	Mean	Mean	Mean	
1 Radiation safetyrowhead	5.143	6.056	6.095	H(2) = 2.580 p = 0.275
2 File verificationrowhead	4.190	5.844	6.333	H(2) = 3.417 p = 0.181
3 Positioning and immobilisationrowhead	**5.071**	**6.606**	**6.786**	**H(2) = 7.779 p = 0.020**
4 Radiotherapy treatment deliveryrowhead	**5.057**	**6.613**	**6.857**	**H(2) = 6.610 p = 0.037**
5 Image verification of patient setuprowhead	**4.476**	**5.934**	**6.738**	**H(2) = 7.951 p = 0.019**
6 Equipment quality assurancerowhead	**2.536**	**4.735**	**4.893**	**H(2) = 6.317 p = 0.043**
7 Professional and ethical practicerowhead	**4.733**	**6.467**	**6.343**	**H(2) = 10.603 p = 0.005**
8 Patient carerowhead	4.457	6.113	6.311	H(2) = 4.842 p = 0.089
9 Pharmacologyrowhead	**2.714**	**3.118**	**1.000**	**H(2) = 10.014 p = 0.007**
10 Research and educationrowhead	**2.679**	**4.703**	**5.595**	**H(2) = 9.158 p = 0.010**
11 Quality and risk managementrowhead	**3.619**	**5.459**	**5.952**	**H(2) = 8.518 p = 0.014**
12 Management and leadershiprowhead	**2.893**	**4.422**	**5.714**	**H(2) = 6.347 p = 0.042**
13 Decision makingrowhead	4.357	5.266	5.786	H(2) = 3.301 p = 0.192
14 Teamwork and multidisciplinarityrowhead	**4.607**	**5.969**	**6.571**	**H(2) = 8.027 p = 0.018**

Table 5
Mean competency score according to the use of international reference documents (significant results highlighted in bold).

	The course follows at least one reference document (n = 24)	The course does not follow any reference document (n = 12)	Kruskal Wallis
	Mean	Mean	
1 Radiation safetyrowhead	6.146	5.833	H(1) = .783 p = 0.376
2 File verificationrowhead	5.764	4.917	H(1) = .649 p = 0.420
3 Positioning and immobilisationrowhead	6.542	6.125	H(1) = .354 p = 0.552
4 Radiotherapy treatment deliveryrowhead	6.558	5.900	H(1) = 1.308 p = 0.253
5 Image verification of patient setuprowhead	**6.160**	**4.889**	**H(1) = 9.036 p = 0.003**
6 Equipment quality assurancerowhead	4.115	4.125	H(1) = .000 p = 0.987
7 Professional and ethical practicerowhead	6.274	5.683	H(1) = .485 p = 0.486
8 Patient carerowhead	**6.089**	**4.954**	**H(1) = 4.292 p = 0.038**
9 Pharmacologyrowhead	3.097	2.139	H(1) = .312 p = 0.576
10 Research and educationrowhead	**4.986**	**3.229**	**H(1) = 5.889 p = 0.015**
11 Quality and risk managementrowhead	**5.619**	**4.083**	**H(1) = 6.292 p = 0.012**
12 Management and leadershiprowhead	**5.073**	**3.000**	**H(1) = 7.479 p = 0.006**
13 Decision makingrowhead	**5.833**	**4.125**	**H(1) = 6.227 p = 0.013**
14 Teamwork and multidisciplinarityrowhead	6.115	5.375	H(1) = 2.166 p = 0.141

However, harmonisation limits the production of new knowledge and development, since all graduates would exit with the same set of abilities and expertise.[37] Additionally, the programmes may not be in tune with the actual needs of the society, since the needs vary between countries.[37,38] Also, changes in education often faces resistance by stakeholders in education whilst stakeholders in clinical practice may be resistant to changes in education since these often bring about changes in the profession.[39]

Factors associated with the level of graduates' competency in linear accelerator tasks

Most course characteristics showed an association with graduates' competency level regarding linear accelerator tasks. However, the different features of the programmes seem to be related to different competency dimensions. Programmes with higher academic levels and longer programme durations were associated with better developed non-technical competencies (such as *Quality and risk management*). In addition, more extended programmes showed improved *Research and education* competency, agreeing with previous literature which suggested that there is a relationship between education programmes duration and research competency level.[40,41] Also, Fig. 9 showed the impact that programme duration has in *Research and education* competency level.

On the other hand, the results suggest that more extended clinical placement (general and RT-specific) and a more substantial proportion of RT in the educational programme allow the graduates to develop better technical competencies related to the linac (such as *Equipment quality assurance* or *Patient care*). The bivariate plots (Figs. 9–14) depict examples of the influence of these factors on different competencies. These figures also show that even for significant correlations, the impact of the various programme characteristics is not the same.

Since very few countries offer courses with academic levels different from EQF6 and specialisms other than dual-qualification, it may be challenging to see statistical significance even if there is a difference. RT-only programmes only showed statistically higher levels of competency in *Equipment quality assurance*. However, these programmes also presented a statistically higher proportion of the curriculum and placement devoted to RT, which are correlated with increase development of other technical competencies.

There was a lack of prior research on the relationship between linac-specific competencies and training at the undergraduate level. However, the existing literature agrees that adequate training is of utmost importance to develop image verification competencies.[42,43] This particular subject, is possibly more discussed in scientific publications because the role of TRs in this task is not yet well established.

This study also demonstrated that courses with a large proportion of the clinical training in skill labs have a lower development of *Pharmacology* competencies. A possible explanation is that simulation may reduce the contact with actual clinical practice, suggesting that pharmacology applied to radiotherapy may be

Table 6
Mean competency score according to whether the programme uses EFRS's and ESTRO's benchmarking document in the course design.

	The course follows EFRS's reference document (n = 18)	The course does not follow EFRS's reference document (n = 18)	
	Mean	Mean	
5 Image verification of patient setuprowhead	6.278	5.194	H(1) = 7.410 p = 0.006
8 Patient carerowhead	6.254	5.168	H(1) = 5.449 p = 0.020
10 Research and educationrowhead	5.134	3.667	H(1) = 4.398 p = 0.036
11 Quality and risk managementrowhead	5.780	4.435	H(1) = 5.518 p = 0.019
	The course follows ESTRO's reference document (n = 14)	The course does not follow ESTRO's reference document (n = 22)	
	Mean	Mean	
10 Research and educationrowhead	5.304	3.826	H(1) = 4.911 p = 0.027
12 Management and leadershiprowhead	5.607	3.602	H(1) = 7.792 p = 0.005

mostly learned in clinical practice. Even though ample literature shows the learning benefits of simulated training,[44,45] there is also literature which agrees, that despite the benefits of simulation, there is no improvement in learning.[46]

The current educational paradigm is that course objectives should be defined in terms of learning outcomes (instead of teaching objectives).[47–51] The EQF for lifelong learning recommends that the *competencies* should be defined in the learning outcomes, reflecting responsibility and autonomy in the tasks performed.[12] However, the results showed that neither the inclusion of competencies in the learning objectives nor the regulation of the learning outcomes at the national level affects the competency level of graduates. However, the lack of registration to practise significantly affects the development of both technical and non-technical competencies.

The use of international reference guidelines for the design of the course curriculum improves both technical (such as *Image verification of patient setup*) as well as non-technical competencies (such as *Decision making*), especially when reference documents produced by EFRS and ESTRO are used. *Research and education* competencies are also more developed in courses that follow these guidelines.

The results showed how programme characteristics influence competency level. As such, besides hindering the movement of professionals between countries, the differences in course characteristics can arguably have an impact on the care that is provided to RT patients. It is essential to highlight that these results do not aim to identify which countries have less or more developed competencies since some countries show lower levels of specific competencies and higher levels of others. However, the misalignment between EU countries with regards to the competency of TRs and the potential to compromise patient safety, is crucial to note. Further studies are recommended to assess this relationship.

In most countries, the professional regulatory body dictates most course characteristics, while others are decided by the educational institutions.[4] As such, this study presents evidence that can be used by these stakeholders to facilitate decision-making when trying to achieve excellence in radiotherapy education. Nevertheless, this data is vital for the whole professional community, including TRs, employers, students, researchers, individuals wishing to move across the EU, professional bodies or anyone interested in these professional issues.

Limitations

Not all EU countries are represented in the study. The margin of error is of 12.98% and including more countries would further decrease this error. A margin of error could not be calculated for the radiotherapy programmes since there is no information available on how many programmes exist in the EU.

Whenever statistical tests are done, there is the possibility that statistical significance can result from chance. When a high number of tests are done, the probability that the p-value is above or below the significance value (.05) due to chance increases. As such, values close to .05 should be interpreted with care and further studies would be useful to corroborate (or otherwise) these results.

Although it is expected that the academic staff of the programmes can provide accurate data, there may be some respondent bias. Due to the nature of the data collected, respondents may feel pressured to give more acceptable answers. The researchers tried to minimise this effect by keeping the questionnaire anonymous.

Since this study focused on tasks related to the linac, the effect on other roles in RT or specialisms was not assessed. However, it is understood that specific changes, such as increasing the proportion of RT in the programme, may reflect a decreased competency in other areas, and these should be further studied.

Education is a very complex phenomenon, and it is acknowledged that there may be other confounding factors that were not assessed and may influence competency level such as the number of RT academic staff in the education institution and their expertise, the use of feedback from stakeholders in the programme design, course entry requirements, amongst others. Also, the economic implications of changing these characteristics were not assessed, however, since the data was collected from existing programmes across member-states, applying changes within the limits of the data collected should be feasible.

The scope of this research was to study the competencies developed during the education programmes. However, it is acknowledged that training of TRs is a lifelong process and underdeveloped competencies can be acquired after graduation.

Conclusion

This is the first study to investigate the impact of course characteristics on development of radiotherapy competencies across the EU. This study shows that most of the programmes training radiotherapy professionals across the EU are 3 to 4-year, dual-qualification programmes (in both radiotherapy and medical imaging) at EQF level 6. However, variations can be found: different specialisms, such as RT-only or programmes that include electrophysiology; different academic levels, from EQF level 4 to level 7; and different durations, from one semester to five years. This discrepancy is also significant in terms of duration of clinical placement, the proportion of the programme dedicated to radiotherapy and duration of RT-specific clinical placement.

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Ultimately, these differences in course structures manifested as differences in competencies. Fundamental competency dimensions in the linear accelerator (such as *Radiotherapy treatment delivery, Positioning and immobilisation* and *Professional and ethical practice*) seem to be developed at the highest level across the EU, however, some others were very poorly developed (such as *Pharmacology, Equipment quality assurance* and *Research and education*). Also, a considerable variation between countries is observed in the level of many competencies related to the linac.

It was found that some programme characteristics (such as the academic level or duration of the programme) influence mostly non-technical competencies. In contrast, technical competencies depended on other features (such as specialisms in the programme, duration of placement and proportion of programme dedicated to RT). Interestingly, extensive use of skills labs showed a lower competency level in *Pharmacology*.

The factors that affected the largest number of competency dimensions (both technical and non-technical) were the existence of a mandatory registration process at the national level and the use of international guidelines in the design of the programme. Therefore, both are recommended to be applied at the national and the individual programme level.

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Conflict of interest statement

None.

References

1. Baeza M. Accident prevention in day-to-day clinical radiation therapy practice. *Proc First ICRP Symp Onthe Int Syst Radiol Prot* 2012;**41**(3):179−87. https://doi.org/10.1016/j.icrp.2012.06.001.
2. ICRP. *Prevention of Accidents to Patients Undergoing Radiation Therapy*vol. 86. ICRP Publication; 2000. Published online, http://www.icrp.org/publication.asp?id=ICRP%20Publication%2086.
3. Sá dos Reis C, Pires-Jorge JA, York H, Flaction L, Johansen S, Maehle S. Curricula, attributes and clinical experiences of radiography programs in four European educational institutions. *Radiography* 2018;**24**(3):e61−8. https://doi.org/10.1016/j.radi.2018.03.002.
4. Couto JG, McFadden S, Bezzina P, McClure P, Hughes C. An evaluation of the educational requirements to practise radiography in the European Union. *Radiography* 2018. https://doi.org/10.1016/j.radi.2017.07.009 [Accessed 09 September 2020].
5. Bibault J-E, Franco P, Borst GR, Van Elmpt W, Thorwhart D, Schmid MP, et al. Learning radiation oncology in Europe: results of the ESTRO multidisciplinary survey. *Clin Transl Radiat Oncol* 2018;**9**:61−7. https://doi.org/10.1016/j.ctro.2018.02.001.
6. McNulty JP, Rainford L, Bezzina P, Henner A, Kukkes T, Pronk-Larive D, et al. A picture of radiography education across Europe. *Radiography* 2016;**22**:5−11. https://doi.org/10.1016/j.radi.2015.09.007.
7. McNulty JP, Knapp KM, Brown P. Radiography education in the spotlight. *Radiography* 2017;**23**:S1−2. https://doi.org/10.1016/j.radi.2017.07.007.
8. England A, Geers-van Gemeren S, Henner A, Kukkes T, Pronk-Larive D, Rainford L, et al. Clinical radiography education across Europe. *Radiography* 2017;**23**:S7−15. https://doi.org/10.1016/j.radi.2017.05.011.
9. Eriksen JG, Beavis AW, Coffey MA, Leer JWH, Magrini SM, Benstead K, et al. The updated ESTRO core curricula 2011 for clinicians, medical physicists and RTTs in radiotherapy/radiation oncology. *Radiother Oncol* 2012;**103**(1):103−8. https://doi.org/10.1016/j.radonc.2012.02.007.
10. Williams PL, Berry JE. What is competence? A new model for diagnostic radiographers: Part 1. *Radiography* 1999;**5**(4):221−35. https://doi.org/10.1016/S1078-8174(99)90055-X.
11. Williams PL. Competent to practise? A case foroccupational standards. *Radiography* 1995;**1**(2):121−5. https://doi.org/10.1016/S1078-8174(95)80021-2.
12. European Parliament, European Council. *Recommendation of the European Parliament and of the Council on the establishment of the European Qualifications Framework for lifelong learning.* Published online April 23, 2008, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008H0506(01)&from=EN. [Accessed 17 May 2017].
13. European Parliament, European Council. *Directive 2005/36/EC of the European Parliament and of the Council on the recognition of professional qualifications*. Published September 7, 2005. http://eur-lex.europa.eu/LEXUriServ/LexUriServ.do?uri=OJ:L:2005:255:0022:0142:EN:PDF. [Accessed 09 September 2020].
14. *EFRS European Qualifications Framework (EQF) Level 6 Benchmarking Document: Radiographers.* 2018. https://api.efrs.eu/api/assets/publications/139. [Accessed 9 September 2020].
15. ESTRO. *European Higher Education Area Level 6. Benchmarking document for Radiation TherapisTs*. Published online 2014, https://www.estro.org/ESTRO/media/ESTRO/Education/ESTRO-RTT-Benchmarking-document_rebranded.pdf. [Accessed 9 September 2020].
16. IAEA. *A handbook for the education of radiation therapists (RTTs)*. Published online, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/45/104/45104835.pdf, 2014. [Accessed 2 May 2017].
17. HENRE. *Tuning Template for Radiography in Europe*. Published, http://www.unideusto.org/tuningeu/images/stories/Summary_of_outcomes_TN/Tuning_template_for_Radiography_in_Europe.pdf; 2008.
18. Couto JG, McFadden S, McClure P, Bezzina P, Hughes C. Competencies of therapeutic radiographers working in the linear accelerator across Europe: a systematic search of the literature and thematic analysis. *Radiography* 2019. https://doi.org/10.1016/j.radi.2019.06.004. Published online July 3.
19. Polit DF, Beck CT. *Essentials of nursing research: appraising evidence for nursing practice*. Wolters Kluwer Health/Lippincott Williams & Wilkins; 2010.
20. Hulley SB, Cummings SR, Browner WS, Grady D, Newman TB. *Designing clinical research*. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=n&CSC=Y&PAGE=booktext&D=books&AN=01745919$&XPATH=/PG(0, 2013. [Accessed 5 January 2018].
21. Van Selm M, Jankowski NW. Conducting online surveys. *Qual Quantity* 2006;**40**(3):435−56. https://doi.org/10.1007/s11135-005-8081-8.
22. Leininger MM, editor. *Qualitative research methods in nursing*. Grune & Stratton; 1985.
23. *SAFE EUROPE project. Safe And Free Exchange of EU Radiography Professionals across Europe*. Published n.d. https://www.ulster.ac.uk/research/topic/nursing-and-health/health-and-rehabilitation-technologies/safe-europe. [Accessed 09 September 2020].
24. Boynton PM, Greenhalgh T. Selecting, designing, and developing your questionnaire. *BMJ* 2004;**328**(7451):1312−5.
25. Lawshe CHA. Quantitative approach to content validity. *Pers Psychol* 1975;**28**(4):563−75. https://doi.org/10.1111/j.1744-6570.1975.tb01393.x.
26. Wilson FR, Pan W, Schumsky DA. Recalculation of the critical values for Lawshe's content validity ratio. *Meas Eval Counsel Dev* 2012;**45**(3):197−210. https://doi.org/10.1177/0748175612440286.
27. Almanasreh E, Moles R, Chen TF. Evaluation of methods used for estimating content validity. *Res Soc Adm Pharm* 2018. https://doi.org/10.1016/j.sapharm.2018.03.066. Published online.
28. LoBiondo-Wood G, Haber J, Nursing Research. *Methods and critical appraisal for evidence-based practice*. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1167407, 2014. [Accessed 29 March 2018].
29. Symonds PM. On the loss of reliability in ratings due to coarseness of the scale. *J Exp Psychol* 1924;**7**(6):456−61. https://doi.org/10.1037/h0074469.
30. Colman AM, Norris CE, Preston CC. Comparing rating scales of different lengths: equivalence of scores from 5-point and 7-point scales. *Psychol Rep* 1997;**80**(2):355−62. https://doi.org/10.2466/pr0.1997.80.2.355.
31. Miller GA. The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychol Rev* 1956;**63**(2):81−97. https://doi.org/10.1037/h0043158.
32. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* 2016;**15**(2):155−63. https://doi.org/10.1016/j.jcm.2016.02.012.

33. Cortina JM. What is coefficient alpha? An examination of theory and applications. *J Appl Psychol* 1993;**78**(1):98–104. https://doi.org/10.1037/0021-9010.78.1.98.
34. Atkinson D, Murray M. *Improving Interrater Reliability*. Published online March 20, http://ejournals.um.edu.mt/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED287175&site=eds-live&scope=site; 1987.
35. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 2005;**19**(1):231–40. https://doi.org/10.1519/15184.1.
36. Prentakis AG, Stefanoyiannis AP, Georgiadis KL, Coleman SJ, Foley D, Herlig, et al. Education, training, and professional issues of radiographers in six European countries: a comparative review. *J Eur CME* 2016;**5**(1):31092. https://doi.org/10.3402/jecme.v5.31092.
37. Sam C, van der Sijde P. Understanding the concept of the entrepreneurial university from the perspective of higher education models. *High Educ* 2014;**68**(6):891–908. https://doi.org/10.1007/s10734-014-9750-0.
38. Gellert C. *Innovation and adaptation in higher education: the changing conditions of advanced teaching and learning in Europe*. J. Kingsley Publishers; 1999.
39. Kurelić Z. How not to defend your tradition of higher education. *Polit Misao Croat Polit Sci Rev* 2009;**46**(5):9–20.
40. Malamateniou C. Radiography and research: a United Kingdom perspective. *Eur J Radiogr* 2009;**1**(1):2–6. https://doi.org/10.1016/j.ejradi.2008.12.003.
41. England A, McNulty JP. Inclusion of evidence and research in European radiography curricula. *Radiography* 2020. https://doi.org/10.1016/j.radi.2020.04.018. Published online May 2020:S1078817420300705.
42. Friel L, Mullaney L. PO-0999: radiation Therapists' image verification training and experience and resulting responsibility: a European study. *Radiother Oncol* 2014;**111**:S144. https://doi.org/10.1016/S0167-8140(15)31117-8.
43. Cox J, Jimenez Y. The radiation therapist's role in real-time EPI interpretation and decision-making. *Eur J Radiogr* 2009;**1**(4):139–46. https://doi.org/10.1016/j.ejradi.2010.04.001.
44. Bleiker J, Knapp KM, Frampton I. Teaching patient care to students: a blended learning approach in radiography education. *Radiography* 2011;**17**(3):235–40. https://doi.org/10.1016/j.radi.2011.01.002. 6pp.
45. Jimenez YA, Lewis SJ. Radiation therapy patient education using VERT: combination of technology with human care. *J Med Radiat Sci* 2018;**65**(2):158–62. https://doi.org/10.1002/jmrs.282.
46. Cheung EYW, Law MYY, Cheung F. The role of virtual environment for radiotherapy training (VERT) in medical dosimetry education. *J Cancer Educ* 2019. https://doi.org/10.1007/s13187-019-01622-2. Published online November 4.
47. Walton H. World summit on medical Education : the changing medical profession. In: *World federation for medical education*. Oxford: Blackwell Scientific Publications; 1993.
48. CEDEFOP. *European guidelines for validating non-formal and informal learning*. Published online, http://www.cedefop.europa.eu/en/publications-and-resources/publications/3073, 2015. [Accessed 2 May 2017].
49. Winterton J. Competence across Europe: highest common factor or lowest common denominator?Winterton J, editor. *J Eur Ind Train* 2009;**33**(8/9):681–700. https://doi.org/10.1108/03090590910993571.
50. European Centre for the Development of Vocational Training. In: *Defining, writing and applying learning outcomes: a European handbook*. Publications Office of the European Union; 2017.
51. Harden RM. Developments in outcome-based education. *Med Teach* 2002;**24**(2):117–20. https://doi.org/10.1080/01421590220120669.