Title

Development and validation of a psychometric scale for assessing healthcare professionals' knowledge in radiation protection

Authors

First author (corresponding author): Tanja SCHRODERUS-SALO MHSc, Radiographer; Research Unit of Nursing Science and Health Management, University of Oulu, Oulu University Hospital, Oulu, Finland

Mailing Address:
Research Unit of Nursing Science and Health Management
Faculty of Medicine
P.O. Box 5000
FI- 90014 University of Oulu
Tel.: +358 40 4113913
Email: tanjaschroderussalo@gmail.com

Second author: Lassi HIRVONEN MHSc, Radiographer; Research Unit of Nursing Science and Health Management, University of Oulu, Oulu, Finland
Email: lassi.hirvonen@ksshp.fi

Third author: Anja HENNER PhD, Principal Lecturer; Degree Programme in Radiography and Radiation Therapy, Oulu University of Applied Sciences, Kiviharjuntie 4, 90220 Oulu, Finland
Email: Anja.Henner@oamk.fi

Fourth author: Sanna AHONEN PhD; Academic Affairs, University of Oulu, Oulu, Finland
Email: sanna.ahonen@oulu.fi

Fifth author: Maria KÄÄRIÄINEN PhD, Professor, RN; Research Unit of Nursing Science and Health Management, University of Oulu, Oulu, Finland; Medical Research Center Oulu, Oulu University Hospital and University of Oulu, Oulu, Finland
Email: maria.kaariainen@oulu.fi

Sixth author: Jouko MIETTUNEN PhD, Professor; Center for Life Course Health Research, University of Oulu, Oulu, Finland; Medical Research Center Oulu, Oulu University Hospital and University of Oulu, Oulu, Finland
Email: jouko.miettunen@oulu.fi

Seventh author: Kristina MIKKONEN PhD, postdoctoral researchers; Research Unit of Nursing Science and Health Management, University of Oulu, Oulu, Finland
Email: Kristina.mikkonen@oulu.fi
Twitter: @Kristinamikkon
ORCID: https://orcid.org/0000-0002-4355-3428

Aknowledgement:

We would like to acknowledge the nurses who took their time to answer the survey and take part in the research. We would also like to acknowledge Sees-Editing Ltd (http://www.seesediting.co.uk) service for improving the language and helping us to communicate our findings to readers of the Journal.

Conflict of interest: None

Funding statement: None

Abstract

Introduction: Healthcare professionals must sufficiently understand ionising radiation and the associated protection measures to avoid unnecessarily exposing patients and staff to ionising radiation. Hence, a proper safety culture is important to lowering health risks. The development and establishment of an instrument that can indicate healthcare professionals' understanding/knowledge of radiation protection concepts can greatly contribute to a good safety culture.

Aim: The purpose of the present study was to develop and psychometrically test the Healthcare Professional Knowledge of Radiation Protection (HPKRP) self-evaluation scale, which was designed to measure the knowledge level of radiation protection by healthcare professionals working with ionising radiation in a clinical environment.

Methods: The presented research employed a cross-sectional study design. Data were collected from eight Finnish hospitals in 2017. A total of 252 eligible nurses responded to the newly developed HPKRP scale. The face and content validity were tested with the Content Validity Index (CVI). Explorative factor analysis was used to test construct validity, whereas reliability was tested with Cronbach’s alpha.

Results: Overall S-CVI for the HPKRP scale was 0.83. Exploratory factor analysis revealed a three-factor model for the HcPCRP scale containing 33 items. The first factor was defined by *Radiation physics and principles of radiation usage*, the second factor by *Radiation protection,* and the third factor by *Guidelines of safe ionising radiation usage*. These three factors explained 72% of the total variance. Cronbach’s alpha coefficient for the scale ranged from 0.93 to 0.96.

Conclusion: The results provide strong evidence for the validity and reliability of the HPKRP scale. Additionally, educators can use the scale to evaluate healthcare students' understanding in radiation safety before and after education.

Highlights

1. There is a lack of psychometrically tested instruments that measure radiation protection knowledge among healthcare professionals.
2. The HPKRP scale was designed with a focus on safe radiation use in the clinical environment.
3. This instrument can be used to measure healthcare professionals’ knowledge in radiation protection.
4. The instrument can be used to measure the effectiveness of radiation education and assess the current state of knowledge in radiation safety among healthcare professionals.

Keywords

radiation protection knowledge
healthcare professional
instrument development
ionising radiation
psychometric testing

Introduction

The ionising radiation used in healthcare to examine and treat a patient is governed by international regulations[1-3]. Furthermore, there are strict criteria for when ionising radiation can be used, including justification of the benefits and risks of medical exposure, optimisation of the patient dose to the lowest achievable dose level that provides sufficient image quality, and that the individual dose does not exceed the limits set for staff and population[1-3]. Radiation use is a crucial part of radiation protection, which includes the optimisation of ionising radiation use and compliance with general radiation safety regulations[1,3-5]. The use of ionising radiation is so strictly regulated because it may cause health risks. Radiation safety standards have been established to protect both people and the environment from the harmful effects of ionising radiation. According to the international safety standards (ICRP, WHO, IAEA), protection must be optimised to the highest level of safety that is reasonably possible[6-7]. The lack of knowledge regarding ionising radiation among healthcare professionals may render them unable to effectively protect themselves and their patients[8-10].

Nurses may participate in several medical ionising radiation procedures. These procedures occur in a controlled area and, in this way, exposure to ionising radiation is restricted to, for example, the operating theatre or the cardiology laboratory[8-9,11]. When a patient is exposed to ionising radiation in the procedures guided with fluoroscopy, staff members are exposed to the scattered radiation[12]. Tissue reactions, previously referred to as 'deterministic effects', depend on the amount of radiation exposure, and health effects such as skin damage and blood changes, among others, will be more severe at higher doses[12-14]. Tissue reactions have appeared following both interventional radiology and cardiology procedures[15-16]. In this way, exceeding the radiation threshold seriously endangers the health of patients and staff[11]. The stochastic effects of radiation include tumours and leukaemia and occur over long periods of time due to modifications in genetic material[13-14]. Healthcare professionals should understand the potential stochastic risks of exposure to ionising radiation whereas patients should be aware of both stochastic and deterministic risks[11].

There is a lack of knowledge and skills among healthcare professionals (e.g. radiographers, medical practitioners and nurses) regarding the safe use of radiation and the associated safety culture[8-10,17-19]. According to the latest evidence, healthcare professionals do not have sufficient skills to effectively communicate benefit-risk information about paediatric imaging examinations[18-19]. The knowledge, skills and attitudes on radiation protection of healthcare professionals have been measured in multiple studies, all of which applied their own instruments[8-10,17,20-22]. Dianati et al. (2014) validated a questionnaire and checklist measuring radiation protection knowledge and behaviours by conducting a study with nurses. However, the questionnaire was limited to measuring variables categorically and, as such, could not provide information on nurses' levels of knowledge on radiation protection. Tok et al. (2015) studied the attitudes and knowledge of ionising radiation of healthcare professionals working in the operating theatre. However, the authors did not provide any information on the validation of the instrument. A validated questionnaire developed by Maharjan (2017) measured radiographers' and radiography students' awareness of radiation protection but was not applicable for measuring other healthcare professionals' awareness of radiation safety.

The psychometric testing of a newly developed instrument evaluates the instrument's quality by quantifying reliability and validity[23]. Instruments are commonly developed in the behavioural or social sciences to measure participants' social and/or psychological aspects and can also include variables as part of a broader theoretical framework[24]. Validity describes the degree to which an instrument measures what it claims to measure[24], whereas an instrument's reliability denotes the accuracy, consistency and reproducibility of the measured scores[25-26]. The determination of face and content validity, construct validity and the reliability coefficient is one way to confirm an instrument's reliability and validity[26].

However, it has been suggested that the absence of a reliable scale results in unsystematically collected and unreliable data[27-28]. According to published evidence[8,10-11] and regulations[1-3], all healthcare professionals who are involved in the use of ionising radiation need to possess adequate competence (knowledge, skills and attitudes) in radiation safety. This competence comprises three areas: 1) knowledge of principles, theories and practical examples concerning the physical background of radiation; 2) skills of the basic principles of radiation exposure in the healthcare setting; and 3) responsibility and autonomy in recognising radiation hazards. All healthcare personnel in the European Union should have radiation competence that matches the fifth of six levels described in the European Qualification Framework[4,29]. In Finland, healthcare professionals do not receive any formal radiation protection education. For this reason, educational institutions differ greatly in the extent to which radiation safety is covered by the curriculum. However, all Finnish healthcare professionals must demonstrate a certain level of radiation safety competence, which is defined by guidelines from the Radiation Protection and Nuclear Safety Authority[30].

Professional competence is understood in this study as an attribute that includes the knowledge, skills and attitudes necessary for providing the required level of quality and capability[31]. In this study, radiation knowledge includes areas of *Radiation physics and radiation biology*, *Radiation protection regulation and radiation use in healthcare*, and *Radiation safety at work*.

Methods

Aims

The purpose of the present study was to develop and psychometrically test the Healthcare Professional Knowledge of Radiation Protection (HPKRP) self-evaluation scale, which was designed to measure the knowledge level of radiation protection by healthcare professionals working with ionising radiation in a clinical environment.

The research questions were:

1) What is the face and content validity of the HPKRP scale?

2) What is the construct validity and reliability of the HPKRP scale in measuring healthcare professionals' knowledge in use of radiation protection?

Design

The research employed a cross-sectional survey design.

Participants

Eight organisations from the 19 hospitals in Finland were chosen by stratified random sampling according to territorial representation of the Finnish healthcare system[32-33]. All nurses (N=1500) in four university hospitals and four central hospitals who participate in medical ionising radiation procedures during their daily work were invited to take part in the study during the autumn of 2017. The invited participants comprised the study population. The stratified sampling was guided by pre-determined eligibility criteria, namely, job title of nurse and working with ionising radiation in the operating theatre, first aid clinic or cardiology laboratory.

Data Collection

The participants were invited to participate by email for rapid information delivery and cost-effectiveness[32]. An email was sent by researchers (TSS, LH) to the head nurses of all departments using medical ionising radiation, who then forwarded the email to their nurses working with ionising radiation. The questionnaire was accessible through the Webropol electronic data collection system[34]. The participants were invited three times by their head nurses, with reminders sent every two weeks during the data collection period. The head nurses confirmed with researchers (TSS, LH) every time the reminders were sent to the nurses.

Development process of the HPKRP scale

The instrument was developed in phases: 1) creating of the scale, 2) testing of face and content validity, and 3) testing of construct validity and reliability (see Figure 1).

Generating items

The first consisted of generating items and developing the instrument. This phase started with a study of the theoretical background necessary to develop the instrument, i.e. radiation standards and act[1,3] radiation safety reports[2,4-6] and research articles investigating the phenomenon[8-9,17]. The theoretical framework was built by using content analysis for the chosen literature and organizing data into open codes, sub-categories and three categories. The sub-categories were transformed into items. The categories were transformed into sub-dimensions of the scale.[35] Prior to construct validity testing, the scale included sub-dimensions of: 1) *Radiation physics and radiation biology*; 2) *Radiation protection regulation and radiation use in healthcare*; *and 3) Radiation safety at work* (41 items in total). The HPKRP scale employed a ten-point Likert scale, ranging from 1= no knowledge to 10= full knowledge. The Likert scale is appropriate when an instrument includes a lot of assertions and the researchers want to gain insight into the subject's claims. A participant's response to questions applying the Likert scale is influenced by their level of experience in the field. It can be used to measure qualitative qualities such as attitudes, skill levels, and opinions.[27,33] The scale used in the presented research was developed and validated in Finnish. The English version presented in the manuscript was forward and backward translated according to established scientific practices for translating an instrument[36].

Face and content validity

Next phases were face and content validity testing. The objective of this psychometric testing was to evaluate the quality of the HPKRP scale[23], including face and content validity. Face and content validity were tested before the main data collection by using an expert panel in a focus group setting. The panel included a team of nine professionals who specialised in either ionising radiation or nursing (e.g. physician, radiographer, radiation expert, operating theatre nurse)[37]. Face validity represents the right look of the construct found in the instrument that it is claiming to be measuring[26.] The experts evaluated the face validity of items by judging their content, wording and grammar. Based on the experts' evaluations, any unclear items were revised and clarified. This ensured that respondents would be able to correctly comprehend the items in order to accurately complete the scale[38]. The content validity was tested by evaluating the scale's relevance (1= not relevant; 2= useful but not relevant; 3= quite relevant; 4= relevant). The content validity index (CVI) method was used by rating of items measuring content. The experts' scores were pooled according to the total score averaging method (S-CVI), i.e. individual item method (I-CVI) values were divided by the number of statements. The I-CVI was also calculated by dividing essential claims by the number of experts[37]. The I-CVI threshold was kept at ≥0.78, and S-CVI threshold was kept at 0.82[37].

After face and content validity testing, the HPKRP scale was pilot tested with 22 participants from an operating theatre at a university hospital. The purpose of the pilot test was to evaluate the utility of the scale[39]. We hoped that the pilot testing would result in at least 10 answers to each group, which is considered a reasonable amount of data for minimising errors[39]. The data were transferred from the Webropol electronic data collection system into the SPSS programme in Microsoft Excel format. The main data analysis was performed using SPSS (v23.0, IBM Corporation, Armonk, NY).

Construct validity and reliability of the instrument

The last phase was construct validity and reliability testing. Construct validity was tested after the main data collection using explorative factor analysis (EFA). The aim of EFA was to reduce the items into main factors so that significant correlations could be easily interpreted and understood between the items[40-41]. The KMO test and Bartlett's test of sphericity (BTS) provided values that were used to evaluate EFA sampling adequacy for the model chosen of the scale ($p<0.01$)[40]. The number of factors was defined by number of eigenvalues >1 and scree plot. The Principle Axis Factoring (PAF) method was used in combination with a promax rotation. This rotation method is recommended for factor analysis when the multiple factors are correlated[41]. Since the overall construct being factored is radiation protection it is expected that there will be some correlation among factors. The cut-off for included items to each factor was 0.40[41]. The cross-loading items loading on more than one of the items were removed. The EFA was repeated after removing of cross-loading items to confirm the goodness of fit model. Cronbach's alpha coefficient was used to examine the internal consistency of the scale and thus test instrument reliability[26,33,42]. The Cronbach's alpha coefficient demonstrates an acceptable newly designed instrument if ≥0.70, a well-established instrument if ≥0.80, and a clinically reliable tool if ≥0.90[26-27].

Ethical considerations

Permission to perform this study was obtained from all eight hospitals according to their own research practices. The participants received an informational email about the study that explained the purpose of the study, voluntary participation, anonymity, confidentiality and data handling procedures[43]. The study was carried out in accordance with ethical principles of research[44]. The study did not require permission from an ethics committee since the study did not include patients, underage children or vulnerable groups. It was determined that the research could not cause psychological or physical harm to the participants.[45]

Results

Participants

A total of 252 participants agreed to participate, representing a response rate of 17%. There was no missing data in participants' responses, as the instructions specified that answering all of the items was compulsory. The participants were 85% (n=215) female. The age of study participants ranged from 18 and over 57 years, with a mean value of 32 years (standard deviation 5.81). The educational level varied between diploma level education 33% (n=82), Bachelor's degree from a University of applied sciences 62% (n=157), Master's degree from a University of applied sciences 4% (n=9) and Master's degree from a University 2% (n=4). Most of participants primarily worked in the operating theatre 68% (n=170) or the first aid clinic 21% (n=53). Of all the participants, 47% (n=118) had previously received 1-10 hours of radiation protection education (Table 1).

Face and content validity

The HPKRP scale was developed with 41 items. Testing the face validity of the HPKRP scale resulted in the modification of 20 items, while testing content validity resulted in the modification of nine items, deletion of four items, combination of two items into one item, and creation of five additional items. The I-CVI ranged from 0.66-1. Overall S-CVI, i.e. the mean validity score, for the HPKRP scale was 0.83, which was interpreted as sufficient for a newly developed scale. Following the evaluation of face and content validity, the HPKRP scale included 41 items. The Cronbach's alpha for the pilot study, which was conducted with 22 nurses, was 0.98.

Exploratory factor analysis

The KMO test result for the exploratory factor analysis model chosen for the HPKRP scale was 0.96, while BTS was significant at 8899.39 (df 528, $p<0.001$). Thus, the exploratory factor analysis, which yielded a three-factor model, had adequate sample size. Eigenvalue and scree plot determined three factors (see Figure 2). There were 14 items which demonstrated cross-loading; as a result, eight items were deleted, and 33 items remained in the final EFA model. The fit of the EFA model was judged against the theoretical framework of the study and statistical measures of the goodness of fit model. The three-factor loading was explained by 72% of the cumulative percentage of the total variance (Table 2). The first factor, *Radiation physics, biology and principles of radiation usage* (12 items), explained 60.1% of the total variance; the second factor, *Radiation protection* (13 items), explained 7.8% of the variance; and the third factor, *Guidelines of safe ionising radiation usage* (8 items), explained 3.5% of the variance. The first, second and third factors of the EFA model showed Cronbach’s alpha coefficients of 0.96, 0.95, and 0.93, respectively, all of which are above the threshold for a well-established scale.

Discussion

The purpose of the study was to develop and psychometrically test the Healthcare Professional Knowledge of Radiation Protection (HPKRP) self-evaluation scale, which was designed to measure knowledge level of radiation protection by healthcare professionals who work with radiation in the clinical environment. To the best of our knowledge, this is the first study to provide a validated instrument for evaluating healthcare professionals’ radiation knowledge internationally. Instruments presented in earlier studies assessed awareness, understanding and attitudes regarding ionising radiation and protection individually, but not together[20-22]. Previous studies that have presented instruments for measuring radiation protection have been limited to measuring variables categorically or the authors did not provide any information on the validation of the instrument or measured radiographers’ and radiography students’ awareness of radiation protection but was not applicable for measuring other healthcare professionals’ knowledge of radiation safety [20-22]. The instrument presented in this study measures healthcare professionals’ knowledge in three different areas of radiation, namely, physics and radiation biology, regulation concerning radiation protection, and radiation use in healthcare. The items in each area specifically assess the professionals’ understanding, skills and attitudes. This study included a sample size that was satisfactory for testing construct validity, as each item of the scale received eight answers per variable. It is well established that a larger sample size will help confirm psychometric properties[26]. The psychometric testing presented in this study was based on rigid research methodology and instrument development process.

Furthermore, previous attempts to describe knowledge of radiation safety have not applied and/or not presented an underlying theoretical framework. We argue that any new instrument must cover all the theoretical concepts related to radiation protection within healthcare. Support for the content validity of the HPKRP scale was based on the theoretical framework and evidence-based practice. During development of the HPKRP scale, information obtained from radiation safety experts was used to modify, delete and edit instrument items[37]. The selection of which items will be included in the final instrument is always crucial, as poorly developed instruments can cause researchers to draw invalid conclusions about studied phenomena[24,28]. The HPKRP scale offers the possibility for improving radiation protection in the clinical environment and is also applicable to the educational context. The objective of this instrument is to gauge the levels of radiation knowledge among healthcare professionals, determine future training needs and identify development targets both in Finland and on an international level.

Limitations

The study has several limitations. First, the response rate was only 17%. A larger sample size could have provided more reliable results; however, the sample met specific inclusion criteria which reflected the research purpose[32-33]. Power analysis was not possible since no previous studies had used scales that were similar to the one presented in this study. In this way, there was no data available from which to calculate the effect size[46-47]. However, according to the recommendations by DeVon et al. (2007), sampling adequacy for exploratory factor analysis was reached[26]. Furthermore, this study reached eight participants per variable, which exceeds the recommended minimum of five participants per variable[26]. Second, the self-evaluation nature of the questionnaire includes the possibility that professionals will evaluate their own knowledge higher than the actual level it is at. Previous studies have suggested that healthcare professionals have the tendency to overrate their clinical knowledge, skills and/or attitudes when completing self-assessment scoring[48-49]. Third, the generalisability of the presented instrument to other healthcare professionals or environments should be considered with caution, as the instrument should be further tested on healthcare professionals other than nurses working with ionising radiation as well as in another context than the Finnish healthcare system. Another limitation is that the scale does not measure modality-specific competence of professionals specialised in imaging examinations, but rather focuses on healthcare professionals' knowledge of radiation protection. Finally**,** the first factor measuring *Radiation physics, biology and principles of radiation usage* explained 60.1% of the total variance*;* the second factor *Radiation protection* accounted for 7.8% and the third factor measuring *Guidelines of safe ionising radiation usage* explained only 3.5% of the total variance. The theoretical framework guided the authors to keep the third factor in order to be able to measure nurses' knowledge of guidelines of safe ionising radiation usage. We suggest that since the last factor explained only 3.5% of the construct validity of the scale, the factor could be improved in the future by creating new items and/or modifying the content of the existing items. The STROBE (2007) checklist was used to assess the quality of the study, and each of the 22 sections received full points[50].

Conclusion

The validated HPKRP scale presented in this paper has the potential to be used in educational, clinical practice and research settings. The scale can provide valuable information on the state of healthcare professionals’ knowledge of radiation use and safety. Additional studies should be conducted to test and validate this instrument in different contexts and settings.

References

1. Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. 2013. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/CELEX-32013L0059-EN-TXT.pdf.
2. International Commission on Radiological Protection. The 2007 Recommendations of the ICRP. Publication 103. Ann ICRP 2007; 37: 2–4.
3. Radiation act (592/91) Radiation Act 27.3.1991/592. Finnish Government. Available at: http://www.finlex.fi/fi/laki/ajantasa/1991/19910592.
4. European Commission. Radiation protection NO 175. Guidelines on radiation protection education and training of medical professionals in the European Union. Luxembourg: Publications Office of the European Union: 2014. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/175.pdf.
5. International Atomic Energy Agency (IAEA). Applying radiation safety standards in diagnostic radiology and interventional procedures using x-rays. Safety reports series no. 39. Vienna: International Atomic Energy Agency Publishing Section; 2006. Available at: http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1206_web.pdf.
6. International Atomic Energy Agency (IAEA). IAEA safety standards for protecting people and the environment. radiation protection and safety of radiation sources: international basic safety standards. general safety requirements part 3, No. GSR part 3. Vienna: International Atomic Energy Agency Publishing Section; 2014. Available at: http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf?bcsi_scan_8d363d15d0b97123¼0&bcsi_scan_filename¼Pub1578_web-57265295.pdf.
7. Bonn Call-for-Action Joint Position Statement by the IAEA and WHO, 2013. Available at: http://www.who.int/ionizing_radiation/medical_exposure/Bonn_call_action.pdf.
8. Yurt A, Cavusoglu B & Günay T Evaluation of awareness on radiation protection and knowledge about radiological examinations in healthcare professionals who use ionized radiation at work. Mol Imaging Radionucl Ther 2014; 23(2):48-53.
9. Jones E & Mathienson K. Radiation safety among workers in health services. Radiat Saf J 2016; 110(2):52-58.
10. Alotaibi M & Saeed R. Radiology nurses’ awareness of radiation. J Radiol Nurs 2006; 25(1):7-12.
11. Jindal T. The risk of radiation exposure to assisting staff in urological procedures: a literature review. Urol Nurs 2013; 33(3):136-147.
12. Agarwal A. Radiation risk on orthopedic surgery: ways to protect yourself and patient. Oper Tech Sports Med 2011; 19:220-223.
13. United Nations Enviroment Programme. Radiation: effects and sources. 2016. Available at: https://wedocs.unep.org/handle/20.500.11822/7790;jsessionid=53F5CB27020794BD3372ECAEBFF3DCB1
14. United Nations Scientific Committee of the Effects of Atomic Radiation (2017) Sources, effects and risk of ionizing radiation Report to the General Assembly Available at: http://www.unscear.org/docs/publications/2017/UNSCEAR_2017_Report.pdf
15. Baltar S & Miller DL. Patient skin reactions from interventional fluoroscopy procedures. AJR 2013; 202: 335-342.
16. Tsapaki V, Ahmed N, AlSuwaidi JS, Beganovic A, Benider A, BenOmrane A, Borisova R, Economides S, El-Nachef L, Faj D, Hovhannesyan A, Kharita MH, Khelassi-Toutaoui N, Manatrakul N, Mirsaidov I, Shaaban M, Ursulean I, Wambani JS, Zaman A, Ziliukas J, Zontar D & Rehani M. Radiation exposure to patients during interventional procedures in 20 countries: initial IAEA project results. Am J Roentgenol 2009; 193: 559–56.

17. Kim C, Vasaiwala S, Haque F, Pratap K & Vidovich M. Radiation safety among cardiology fellows. Am J Cardiol 2010; 106:125-128.
18. Portelli JL, McNulty JP, Bezzina P & Rainford L. Benefit-risk communication in paediatric imaging: what do referring physicians, radiographers and radiologists think, say and do? Radiography 2018; 24: 33-40. Available at: http://dx.doi.org/10.1016/j.radi.2017.08.009.
19. Portelli JL, McNulty JP, Bezzina P & Rainford L. Radiographers' and radiology practitioners' opinion, experience and practice of benefit-risk communication and consent in pediatric imaging. Radiography 2016; 22: 33-40. Available at: http://dx.doi.org/10.1016/j.radi.2016.08.005
20. Dianati M, Zaheri A, Talari H, Deris F & Rezaei S. Intensive care nurses' knowledge of radiation safety and their behaviors towards portable radiological examinations. Nurs Midwifery Stud 2014; 3(4): e23354.
21. Tok A, Akbas A, Aytan N, Aliskan T, Cicekbilek I, Kaba M & Tepeler A. Are the urology operating room personnel aware about the ionizing radiation? Int Braz J Urol 2015; 451(5):982-989
22. Maharjan S. Radiation knowledge among radiographers and radiography students. Radiography Open 2017;3(1). Available at: http://dx.doi.org/10.7577/radopen.2000.
23. Polit DF & Beck CT. Nursing research: generating and assessing evidence for nursing practice. 8th edn. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins; 2008.
24. DeVellis R. Scale development: theory and applications. 4th edn. Thousand Oaks: Sage Publications; 2016.
25. Cook DA & Beckman TJ. Current concepts in validity and reliability for psychometric instruments: theory and application. Am J Med 2006; 119: 166.
26. DeVon H, Block M, Moyle-Wrigth P, Ernst D, Hayden S, Lazzara D, Savoy S & Kostas-Polston E. A psychometric toolbox for testing validity and reliability. J Nurs Scholarsh 2007; 39:155-164.
27. Rattray J & Jones MC. Essential elements of questionnaire desing and development. Journal of Clin Nurs. 2005; 16:234-243.
28. Waltz C, Strickland O & Lenz E. Measurement in nursing and health research. 4th edn. New York: Springer; 2010.
29. ICRP. Education and training in radiological protection for diagnostic and interventional procedures. ICRP Publication 113. Ann ICRP 2006; 39(5).
30. Paasonen T. Radiation protection training in Finland for basic and further education of healthcare personnel 2010 (in Finnish). Helsinki: Radiation and Nuclear Safety Authority; 2011. Available at: https://www.julkari.fi/bitstream/handle/10024/124204/stuk-b133.pdf?sequence=1
31. Meretoja R. Nurse competence scale. Doctoral dissertation. Turku, Finland: Annales Universitatis Turkuensis; 2003.
32. Haber J. Sampling. In: LoBiondo-Wood G & Haber J, editors. Nursing research – methods and critical appraisal for evidence-based practice, Maryland Heights: Mosby Elsevier; 2006.
33. Polit DF & Beck CT. Nursing research: generating and assessing evidence for nursing practice. 9th edn. Philadelphia: Wolters Kluwer/ Lippincott Williams & Wilkins; 2012.
34. Webropol. Released 2002. Huovitie 3, 00400 Helsinki, Finland.
35. Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. Journal of Advanced Nursing, 62(1), 107–115.
36. Vizcaya-Moreno, María Flores et al. Country Validation of the CLES-Scale: Linguistic and Cultural Perspectives. In Saarikoski M amd Strandell-Laine C, editors. The CLES-Scale: An Evalution Tool for Healthcare Education, Springer International Publishing AG; 2018, p. 31-45. Available at: https://www.springer.com/gp/book/9783319636481
37. Gilbert GE & Prion S. Making sense of methods and measurement: Lawshe's Content Validity Index. Clin Simul Nurs 2016; 12:530-531.

38. Drennan J. Cognitive interviewing: verbal data in the desing and pretesting of questionnaires. J Adv Nurs 2002;42(1):57-63.
39. Hertzog M (2008) Considerations in Determining Sample Size for Pilot Studies. Research in Nursing and Health 31: 180-191.
40. Williams B, Onsman A & Brown T. Exploratory factor analysis: a five-step guide for novices. J Emerg Prim Health Care 2010; 8(3).
41. Yong AG & Pearce S. A beginner's guide to factor analysis: focusing on exploratory factor analysis. Tutor Quant Methods Psychol 2013; 9(2):79-94.
42. Bruns N & Grove SK. The practice of nursing research: conduct, critique & utilization. 5th edn. Philadelphia: W.B. Sauders Company; 2001.
43. Gallagher B, Berman AH, Bieganski J, Jones AD, Foca L, Raikes B, Schiratzki J, Urban M & Ullman S. National human research ethics: a preliminary comparative case study of Germany, Great Britain, Romania, and Sweden. Ethics Behav 2015;26(7):586-606.
44. RCR (2012) Finnish Advisory Board on Research Integrity. Responsible conduct of research and procedures for handling allegations of misconduct in Finland- RCR guidelines. Finnish advisory board on research integrity. Available at: http://www.tenk.fi/sites/tenk.fi/files/HTK_ohje_2012.pdf.
45. Medical Research Act 488/1999, 295/2004, 794/2010. Helsinki: Ministry of Social Affairs and Health. Available at: http://www.finlex.fi/fi/laki/kaannokset/1999/en19990488.
46. Cohen J. A power primer. Quant Methods Psychol 1992; 112(1): 155–159.
47. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Front Psychol 2013; 4: 863.
48. Scaffidi MA, Grover SC, Carnahan H, Khan R, Amadio JM, Yu JJ, Dargavel C, Khanna N, Ling SC, Yong E, Nguyen GC & Walsh CM. Impact of experience on self-assessment accuracy of clinical colonoscopy competence. Gastrointestinal Endoscopy 2018; 87: 827-836. doi.org/10.1016/j.gie.2017.10.040
49. Rezaiefar P, Forse K, Burns JK, Johnston S, Muggah E, Kendall C & Archibald D. Does general experience affect self-assessment? Clin Teach 2018. Available at: doi.org/10.1111/tct.12797
50. STROBE. STROBE statement—checklist of items that should be included in reports of observational studies. 2007. Available at: https://www.strobe-statement.org/fileadmin/Strobe/uploads/checklists/STROBE_checklist_v4_combined.pdf.

Table 1. Participant background (n=252)

Variable	n	%
Age		
18-27	31	12.3
28-37	79	31.3
38-47	65	25.8
48-57	59	23.4
over 57	18	7.2
Gender		
Female	215	85.3
Male	37	14.7
Work experience (years)		
0-4	45	17.9
5-9	44	17.5
10-14	43	17.1
15-20	41	16.3
over 20	79	31.2
Education level in the health sector		
Diploma level education	82	32.5
Bachelor’s degree, university of applied science	157	62.3
Master’s degree, university of applied science	9	3.6
Master’s degree of university	4	1.6
Work unit		
operating theater	170	67.5
cardiology laboratory	29	11.5
first aid clinic	53	21
Radiation safety education, in hours		
under 1	50	19.8
1-10	118	46.8
10-20	50	19.8
above 20	34	13.6

Table 2. HPKRP exploratory factor analysis (n = 252)

Items	Factor 1	Factor 2	Factor 3
1. I know how ionising radiation is produced.	0.965		
2. I know the differences between ionising and non-ionising radiation.	0.937		
3. I know the differences between electromagnetic and ionising radiation.	0.917		
4. I know the characteristics and physical features of x-rays.	0.845		
5. I know how the harmful effects of medical radiation are caused.	0.823		
6 I can describe the deterministic effects of a certain radiation dose.	0.759		
7. I can describe the stochastic effects of a certain radiation dose.	0.717		
8. I know the justification principles for medical radiation examinations.	0.601		
9. I understand the equations and measures in medical radiation examinations.	0.573		
10. I understand the meaning of the As Low As Reasonably Achievable principle in radiation examinations.	0.529		0.427
11. I know the fundamental principles of radiation protection.	0.483		
12. I have obtained enough education about the use of radiation in medical examinations.	0.461		
13. I know how to properly use personal protective equipment (PPE).		0.979	
14. I know how to properly use the radiation protection equipment for patients.		0.889	
15. I pay attention to the other personnel while working in a controlled area and using radiation.		0.859	
16. I know how to document all the essential information concerning the use of radiation.		0.851	
17. I am aware that information concerning a patient’s radiation dose must be written down in patient records.		0.705	
18. I know the protocols concerning radiation workers who are pregnant		0.704	
19. I try to promote agreed safety protocols concerning radiation dose and radiation usage in my daily work and actions.		0.673	
20. I understand the factors affecting a patient’s radiation dose.		0.626	
21. I know how to account for differences between adult and child/adolescent patients in radiological examinations.	0.408	0.598	
22. I understand the meaning of the inverse square law in radiation protection.		0.568	
23. I am able to asses my actions critically and comprehensively while working with medical radiation.		0.511	
24. I am aware of the radiation safety arrangements at my work.		0.492	
25. I understand the meaning of radiation safety culture.		0.434	
26. I know the meaning of warning signs regarding radiation safety.			0.752
27. I observe and notice the warning signs concerning radiation while working in a controlled area.			0.712
28. I know how radiation workers’ health monitoring has been organized.			0.616
29. I am aware of the classification of radiation workers.			0.571

30. I know how to report abnormal events in radiation usage.			0.549
31. I understand the situations in which the" abnormal event notification" must be performed.			0.533
32. I understand the procedures for how radiation exposure in radiation workers is monitored.			0.507
33. I understand the principle of dose limitation in radiation protection.			0.417
Eigenvalue	19.830	2.560	1.146
Percentage of factor model	60.0921	7.758	3.472
Total percentage of factor model			71.323
Cronbach's Alpha	0.964	0.957	0.937
Cronbach's alpha on total scale			0.979

* Extraction method: principal axis factoring with Promax rotation, presented in Patter Matrix, only loading factors ≥0.400 are presented in the table

Figure 1. Development process of the HPKRP scale

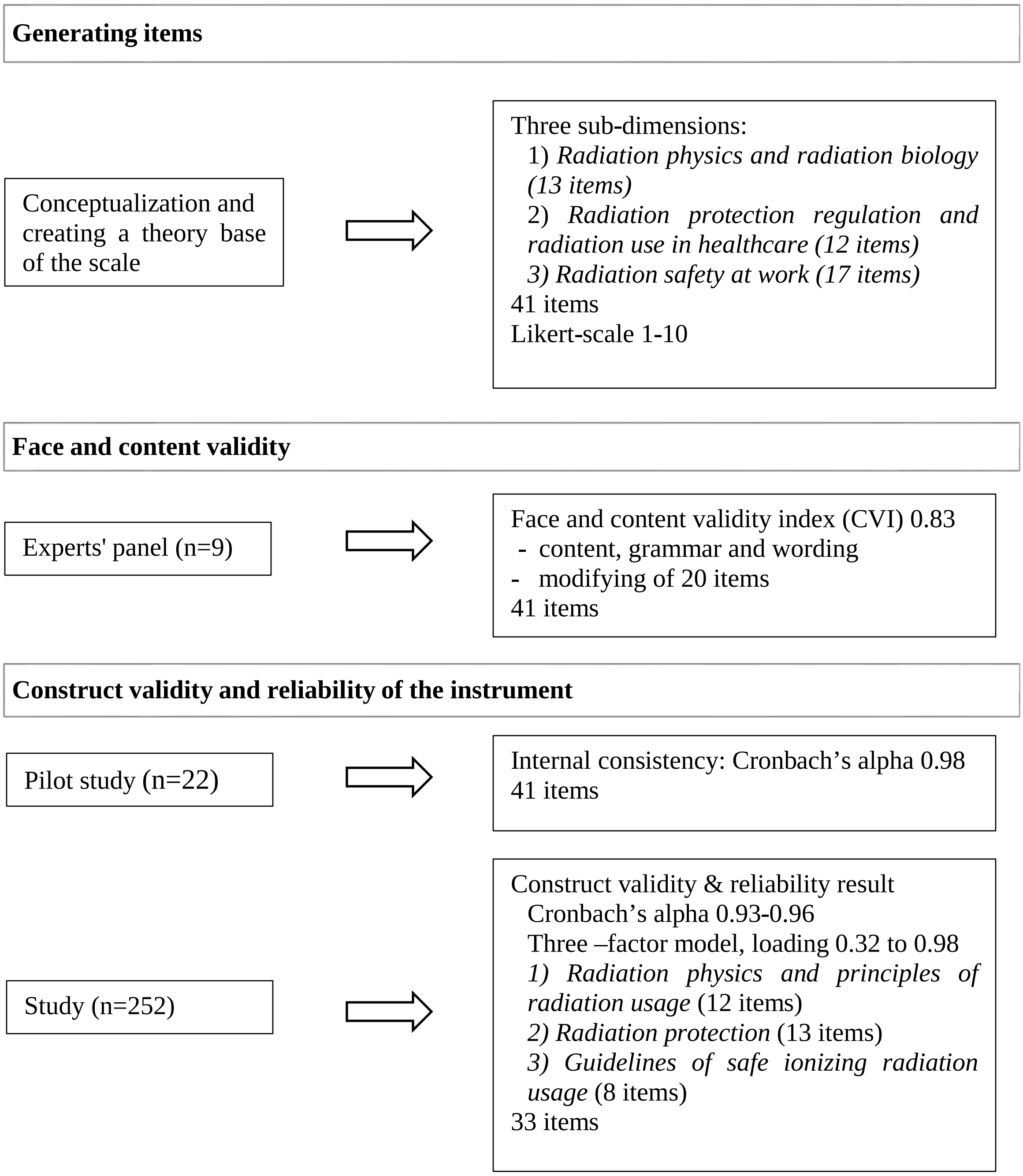

Figure 2. Scree plot of HPKRP scale