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ARTICLE

The impact of needs-based education on the change of knowledge and attitudes towards medical genetics in medical students

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Abstract

In this research we aimed to (1) develop and validate a new questionnaire examining attitudes and knowledge towards medical genetics, (2) examine the knowledge and attitudes towards medical genetics in students of the Medical Faculty in Rijeka, Croatia and (3) evaluate the impact of education from the mandatory course Medical Genetics on the change of knowledge and attitudes. The study was conducted on 191 fifth- and sixth-year students of the Integrated Undergraduate and Graduate University Study of Medicine in the academic year 2019/2020. Students completed the validated online questionnaire anonymously and voluntarily. Fifth-year students completed the questionnaire twice (beginning/end of the course), while sixth-year students completed the questionnaire once, 3 months after completing the course. The education was carefully designed for medical students according to the CoreCompetences in Genetics for Health Professionals in Europe issued by the European Society of Human Genetics. Using the Kruskal–Wallis test, a statistically significant difference was found between fifth year before and after education and between the fifth year before education and sixth year for (a) total knowledge ($P < 0.001$), (b) total attitudes ($P < 0.001$) and (c) personal assessment of knowledge in medical genetics ($P < 0.001$). Moreover, positive attitudes were associated with higher levels of knowledge. In conclusion, our results emphasise the importance of needs-based education in medical genetics for medical students, which is indispensable for the increase in the level of knowledge and development of positive attitudes in order to provide better health care for patients with genetic disorders.

Introduction

Genetic literacy is a form of health literacy, which includes the literacy on basic concepts in human genetics, as well as medical genetics. As such, it is a critical prerequisite for appropriate care for patients with (possible) genetic disorders. An indispensable portion of patients in cardiology, gastroenterology, neurology, oncology, gynecology and paediatrics are those with (possible) genetic disorders, indicating an inevitable need for cooperation between medical geneticists and physicians who are not specialists in medical genetics. In addition, medical genetics is one of the fastest-developing medical specialisations, and advances in the development of new, comprehensive genetic testing methods are becoming increasingly integrated into various parts of medicine. Unfortunately, this progress has not been accompanied by an adequate level of genetic literacy in medical students, physicians and the general population, including patients. Therefore, the requirements for an adequate and needs-based education in medical genetics for each group are increasing.

In previous studies evaluating the genetic literacy in physicians and the general population, only knowledge or only attitudes towards medical genetics were examined [1–37]. The results show that knowledge in all groups is insufficient. Moreover, the level of knowledge in physicians was found to be too low to guarantee an adequate answer to patient inquiries about medical genetics, genetic tests and new advances in the field. This lack of genetic knowledge is, as far as it is known, a global problem [9].

Supplementary information The online version of this article (https://doi.org/10.1038/s41431-020-00791-9) contains supplementary material, which is available to authorised users.

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In addition, a series of previous studies examined attitudes and/or knowledge and the need for education of health professionals; however, there was no study evaluating both attitudes and knowledge in medical students. Moreover, to our best knowledge, no research has been conducted examining the impact of mandatory, comprehensive, needs-based education on the change in knowledge and attitudes towards medical genetics in any group of medical professionals. Such focused good-quality and timely education is crucial for future physicians in order to improve the quality of care and increase awareness of patients with genetic disorders. Therefore, the main aims of this research were to: (1) develop and validate a new questionnaire examining attitudes and knowledge towards medical genetics, (2) examine the knowledge and attitudes towards medical genetics in students of the Medical Faculty in Rijeka, Croatia and (3) evaluate the impact of education from the mandatory course Medical Genetics on the change of knowledge and attitudes.

Participants and methods

All students who participated in the research attended the Integrated Undergraduate and Graduate University Study of Medicine at the Faculty of Medicine in Rijeka, Croatia in the academic year 2019/2020 (indicated in further text as "medical students"). All students participated in the research anonymously and voluntarily. Before completing the questionnaire, all participants were told that the results will not affect the grade from the course Medical Genetics. The research was approved by the Ethics Committee for Biomedical Research of the Medical Faculty of the University of Rijeka, Croatia.

Questionnaire development and validation

Questionnaire development

Considering that our aim was to design a questionnaire for the purpose of determining the knowledge and attitudes towards medical genetics in health professionals, we reviewed the existing literature and questionnaires about medical genetics and genetic testing [1–37]. However, none of them were designed for the specific needs of the medical profession and we therefore decided to construct a new questionnaire intended specifically for the real needs of medical students and physicians.

Knowledge was tested through 27 statements with the option of choosing an answer between correct/incorrect, with the possibility of achieving a maximum of 27 points (one point per correct answer). The first version of the attitude scale consisted of 25 statements on a five-point Likert-type scale: 1: I don't agree at all, 2: I mostly don't agree, 3: I neither agree nor disagree, 4: I agree and 5: I strongly agree.

Participants for questionnaire validation

The validation process was performed in the year 2020 during January. A total of 239 medical students completed the entire questionnaire (105 in the sixth, 95 in the fifth and 39 in the fourth year of study); however, 246 students completed most of the questionnaire. The course of the research is represented in Fig. 1.

Cross-sectional research

Participants

The cross-sectional research included fifth- and sixth-year medical students. A total of 224 subjects were invited to the study (111 in the fifth and 113 in the sixth year). Students completed the online questionnaire, which required 10–15 min to respond.

Methods

Fifth-year students completed the online questionnaire twice, once at the beginning (in the first class) and once at the end (in the last class) of the mandatory course Medical Genetics. Sixth-year students completed the questionnaire only once, 3 months after completing the course to determine whether the knowledge and attitudes implemented through education were long term.

Education

The process of education for medical doctors in Croatia lasts for 6 years, of which the first three are preclinical and the last three clinical years. Students are first exposed to medical genetics in their fifth year.

The course Medical Genetics is a mandatory subject at the Integrated Undergraduate and Graduate University Study of Medicine at the Faculty of Medicine in Rijeka, and consists of 19 h of lectures, 15 h of seminars and 11 h of practicals (three ECTS). In the academic year 2019/2020 it was conducted twice on two different student groups: for the final time in the sixth and, according to the new study programme, in the fifth year. The aim of the course is to describe and explain the basics of a comprehensive approach to a patient with a genetic disease or disorder, or an increased risk for them. The entire course is conducted exclusively through active learning methods and is designed in such a way that students analyse real patients in the form

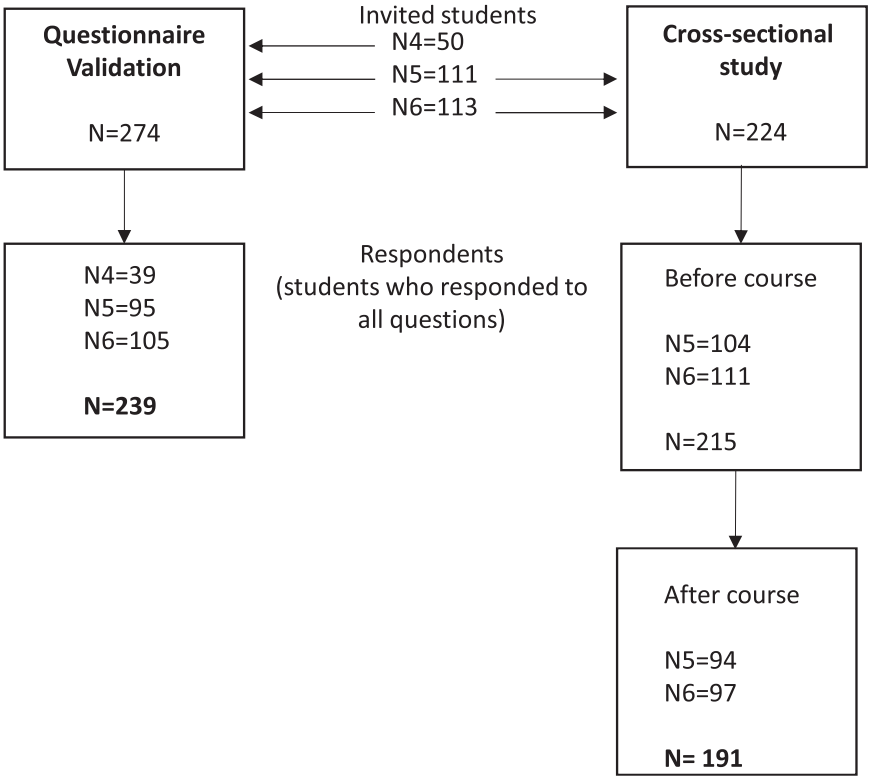

Fig. 1 Flowchart representing the course of the research. Students from fourth year were invited to take part at the questionnaire validation study, because a larger sample is needed for questionnaire validation. In the cross-sectional study only data from students from the fifth and sixth year were consider and processed. *N*4 = fourth-year students; *N*5 = fifth-year students; *N*6 = sixth-year students; *N* = all students.

case studies, thus achieving a simulation of the actual physician–patient relationship in practice. Different active learning techniques were applied during lectures, seminars and practicals to ensure the acquirement of appropriate learning outcomes. The course is divided into five major thematic units that answer the same number of questions related to achieving learning outcomes (How to identify a person with a genetic disorder?; How to choose the appropriate method of genetic testing and basically interpret the results?; How to direct genetic testing in patients with multiple congenital anomalies with or without intellectual disability?; How to approach each patient individually?; How to communicate genetic information to a patient?) (the complete curriculum is available on personal request). The entire course is needs-based for medical students, and learning outcomes, including the cognitive, psychomotor and affective domains, were determined and derived in accordance with key competencies according to Core Competences in Genetics for Health Professionals in Europe published by the European Society of Human Genetics specifically for physicians who are not specialists in medical genetics [38].

Statistical analysis

Statistical analysis was conducted in the programmes Statistica, version 13.3 (StatSoft, Inc., Tulsa, OK, USA) and MedCalc, version 19.2.0 (MedCalc Software, Mariakerke, Belgium).

Development and questionnaire validation

In order to validate the part about attitudes, factor analyses were performed and the factors' reliability was calculated in order to obtain a validated and reliable scale for future use and purpose. To identify the questionnaire's construct validity, principal components factor analysis with oblimin rotation was used, including Scree-plot. Correlations between factors were calculated with Pearson's coefficient of correlation. The reliability of the factors was determined by Cronbach alpha (α) coefficient.

Cross-sectional research

In all analyses, students were divided into three groups and marked with different letters: (1) students of the fifth year before the completed course were marked with the letter A, (2) students after the completed course were marked with the letter B and (3) students of the sixth year were marked with the letter C.

Nominal variables are shown in absolute and relative frequencies. The normality of the distribution of numerical variables was examined by the Kolmogorov-Smirnov test. All numerical variables are shown by median and interquartile range (IQR), except for age, which is shown by median and range. Differences in the frequency of knowledge and attitudes between the three test groups were calculated by the Chi-square test and the post-hoc *T*-test of

proportions. Differences in medians of knowledge and attitudes were examined by the Mann–Whitney test for independent samples, the Kruskal–Wallis test and the post-hoc analysis. The level of statistical significance was determined at $P < 0.05$.

Results

Development and validation of the questionnaire

Principal factor analysis with oblimin rotation determined the factorial structure of the questionnaire. The construct validity was determined by the Scree-test and the interpretability of the factors. A five-factorial structure was disclosed reflecting different aspects of attitudes towards medical genetics, and the reliability of each factor was higher than 0.60. Factors' Eigen values were 4.31, 3.47, 1.80, 1.54 and 1.39. Factor loadings exceeding 0.40 and showed minimal overlap among factors (Supplemental Tables 1–3). Six statements did not fit into any of the factors and were therefore excluded from the questionnaire. The final version of the questionnaire consists of 19 statements divided into five factors explaining 50.04% of the questionnaire variance.

Final version of the questionnaire assessing knowledge and attitudes towards medical genetics (QUAKA-MEDGENE)

The final version of the questionnaire consists of 60 questions divided into four groups: demography, knowledge of medical genetics, attitudes towards medical genetics and one optional group of questions, personal beliefs (Supplemental Material 1). The first group contains eight questions and includes demographic data on respondents, such as gender, age, year of enrolment, the country of graduation from high school, as well as data on previous education in medical genetics and assessment of knowledge and need for education in medical genetics.

Students' knowledge was tested through 27 statements with the option of choosing an answer between correct and incorrect, and they were able to achieve a maximum of 27 points (one point per correct answer). Score statements are divided into four parts: (a) knowledge about the role of genetic factors in medicine (12 statements, 12 possible points), (b) which diseases are caused by genetic, environmental or the combination of genetic and environmental factors? (4 claims, 4 possible points), (c) knowledge about genetic testing (11 claims, 11 possible points) and (d) what do you think is the scope of work of medical geneticists/physicians who are not medical geneticists? (respondents indicate which of the suggested statements describe the scope of work of a medical geneticist and physicians non-specialists in medical genetics).

The third part of the questionnaire examines attitudes towards medical genetics and contains 19 statements that comprise five factors: (1) attitudes towards genetic testing, (2) attitude towards decision making, (3) attitude towards education, (4) attitudes towards genetic testing of mothers and newborns and (5) attitudes towards genetics. Participants rated attitudes on a Likert scale from 1 to 5, and the responses were summed. For the purpose of calculating the total attitude, the particles from the questionnaire were recorded in a way that the maximum number of points (95) corresponded to positive attitude, whereas the minimum number of points (19) corresponded to negative attitude.

The last part of the questionnaire, personal beliefs, contains four questions by which participants indicate on a scale of 1–5 the extent to which they think religious and political attitudes influence them, and which assesses the impact of these factors on knowledge and attitudes about medical genetics.

General information

The questionnaire was completed by 191 respondents: 94 respondents of the fifth year (response rate 84.7%) and 97 respondents of the sixth year (response rate 85.8%). A total of 135 (60%) female students and 89 (40%) male students completed the questionnaire. The median age of the fifth-year respondents was 23 years (range 22–30), while for the sixth year it was 24 years (range 23–29). A total of 192 (79.3%) respondents were Christian and 16.1 % atheists.

A total of 74 (77.9%) respondents in the fifth year and 84 (85.7%) respondents in the sixth year did not have a personal experience with genetic disorders. Additional education in medical genetics aside from the mandatory courses at the faculty was given to four (4.2%) respondents of the fifth and nine (10.1%) respondents of the sixth year.

Knowledge

Total knowledge

The median assessment of own knowledge in medical genetics for respondents in the fifth year before education was 2 out of 5, while after completing the course there was no difference in assessed knowledge between respondents in the fifth year after education and the sixth year, and the median for both groups was 4 of 5 (IQR of 3–4). Such a result shows that there is a statistically significant difference in the assessment of one's own knowledge ($P < 0.001$) before and after education. After the education, the respondents assess their own knowledge with grade 4, and before with a grade 2.

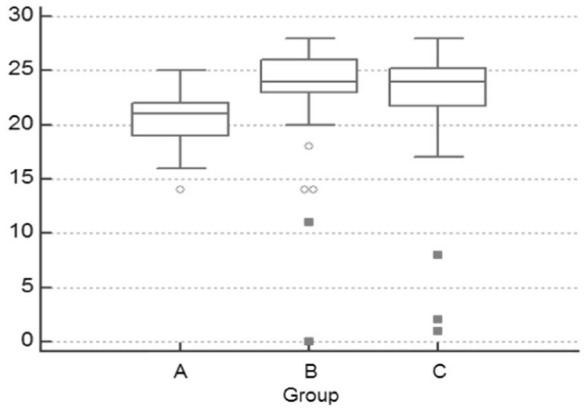

Fig. 2 Total knowledge of medical students before and after education in medical genetics shown by median, interquartile scattering and range. A: students of the fifth year before the completed course, B: students of the fifth year after the completed course and C: students of the sixth year after the completed course.

All three groups of respondents marked the need for knowledge, skills and attitudes in medical genetics in practice with a median grade of 4.

The median for total knowledge of the respondents in the fifth year before education was 21 (IQR from 19 to 22), and after education 24 (IQR from 21.75 to 25.25), as well as for the sixth year (IQR from 23 to 26) (Fig. 2). The Kruskal–Wallis test found that total knowledge differed statistically significantly before and after education in the fifth year ($P < 0.001$). Post-hoc analysis showed that all groups differed statistically significantly, and fifth-year students have the best knowledge immediately after education ($P < 0.05$).

Knowledge about the role of genetic factors in medicine

The second part of the questionnaire examined students' knowledge of the role of genetic factors in medicine through 12 questions. The results are shown in Table 1. Sixth-year students after education have statistically significantly more knowledge about tumour heredity than fifth-year students before education ($P < 0.036$, post hoc ($P < 0.050$)). Students in the fifth and sixth years after education learned statistically significantly more how different changes in one gene can cause several different diseases ($P < 0.004$, post hoc ($P < 0.050$)). Sixth-year students knew significantly more that genetic diseases do not always manifest prenatally or at birth ($P < 0.025$), and that malformation and congenital anomaly are not synonyms ($P < 0.011$) compared to fifth-year students after education (all $P < 0.050$).

Also, students' knowledge of diseases that may be based on genetic, environmental and a combination of factors was examined separately through four questions. The results are shown in Supplemental Table 4. Students in the fifth year before education were statistically significantly less aware of classic familial adenomatous polyposis compared to students after education ($P < 0.050$). Students in the sixth year after education knew significantly more about foetal hydantoin syndrome compared to students in the fifth year before and after education ($P < 0.050$).

Knowledge about genetic testing

Knowledge about genetic testing was examined through 11 questions, and the results are shown in Table 2. In 8 out of 11 questions, a statistically significant difference ($P < 0.001$) was observed in the knowledge about genetic testing before and after medical genetics education. It was noticed that the fifth and sixth years are consistent in knowledge, that is, after education there is no difference in direct and indirect knowledge of students. Questions related to the right of a person to refuse genetic testing ($P < 0.071$), referral of patients by specialists ($P < 0.472$) and ordering a test without his knowledge ($P < 0.090$) were in a high percentage accurately answered even before education, and therefore no statistically significant difference in knowledge after education is observed. On most questions, fifth- and sixth-year students after education have statistically significantly more knowledge compared to fifth-year students before education (all $P < 0.050$).

What do you think is the scope of work of medical geneticists/physicians who are not medical geneticists?

The results are shown in Supplementary Tables 5 and 6. A statistically significant change in opinion ($P < 0.001$) was observed between fifth-year students before education and sixth-year students who were more likely to consider the role of a physician who is not a medical genetics specialist to be lifelong care and interpretation of genetic testing findings. The difference in results ($P < 0.001$) between fifth- and sixth-year students shows that a significantly higher percentage of sixth-year students believe that working in a research laboratory and talking to patients about genetic testing fall within the scope of work of a non-medical geneticist. Lifelong patient care and talking to patients about genetic testing in a significantly higher percentage ($P < 0.001$) fall within the scope of work of a medical geneticist according to the answers of respondents in the fifth year after education and in the sixth year as opposed to answers of fifth year before education. Sixth-year respondents in a significantly higher percentage ($P < 0.001$) believe that ordering genetic tests for patients falls within the scope of work of a medical geneticist from fifth-year students before education.

Table 1 Knowledge about the role of genetic factors in medicine.

Question	Correct answers *n* (%)			*P*
	A	B	C	
All genetic diseases are hereditary	80 (85)	89 (90)	86 (91)	0.350
Carriers of recessive diseases are always healthy	81 (86)	78 (79)	82 (87)	0.217
Gene mutation that causes a disease does not always have to be expressed in the phenotype	87 (93)	89 (91)	91 (97)	0.306
Chromosome changes do not always have to be expressed in the phenotype	60 (64)	73 (74)	70 (74)	0.199
The most common cause of miscarriage are chromosome aberrations	80 (85)	86 (87)	84 (89)	0.634
Assisted reproduction techniques should be offered to all infertile couples regardless of the cause of infertility	78 (83)	90 (91)	83 (88)	0.240
Genetic diseases always manifest prenatally or at birth	91 (97)	90 (93)	94 (100)	0.025[a]
Malformation and congenital anomaly are not synonyms	75 (80)	73 (74)	85 (90)	0.011[b]
Most diseases in humans are caused by changes in one gene	79 (84)	85 (86)	88 (94)	0.102
Different changes in one gene can cause many different diseases	86 (91)	97 (98)	94 (100)	0.004[c]
Most diseases are caused by environmental factors only (e.g., diet and lifestyle)	64 (68)	71 (72)	55 (58)	0.137
Most tumours are hereditary	76 (81)	89 (90)	87 (93)	0.036[d]

A: students of the fifth year before the completed course, B: students of the fifth year after the completed course and C: students of the sixth year after the completed course.

[a]AC vs B.

[b]B vs C.

[c]A vs BC.

[d]A vs C.

Table 2 Knowledge about genetic testing.

Question	Correct answers *n* (%)			*P*
	A	B	C	
A physician may order a genetic test for a patient without their knowledge	88 (94)	96 (98)	90 (99)	0.090
All genetic tests are diagnostic	58 (62)	95 (97)	83 (91)	<0.001[a]
In the Republic of Croatia, new-born screening is conducted only for congenital hypothyroidism and phenylketonuria	41 (44)	81 (83)	81 (89)	<0.001[a]
Gene diseases can be diagnosed with karyotype analysis	39 (41)	77 (79)	72 (79)	<0.001[a]
The same methods of genetic testing are used for diagnosing gene and chromosome changes	75 (80)	92 (94)	89 (98)	<0.001[a]
Pharmacogenomics is currently not clinically applicable because scientific research on the influence of genes on drug metabolism is still underway	55 (59)	93 (95)	87 (96)	<0.001[a]
Genetic testing for Huntington's disease can be conducted in minors	26 (28)	84 (86)	69 (76)	<0.001[a]
Genetic testing for classic familial adenomatous polyposis can be conducted in minors	78 (83)	95 (97)	85 (93)	0.002[a]
Patients are not obliged to inform their family about their results of genetic testing	72 (77)	85 (87)	89 (98)	<0.001[a]
Only medical genetics specialists can refer patients for genetic testing	88 (94)	95 (97)	85 (93)	0.472
Every person has the right to refuse genetic testing	90 (96)	97 (99)	91 (100)	0.071

A: students of the fifth year before the completed course, B: students of the fifth year after the completed course and C: students of the sixth year after the completed course.

[a]A vs BC.

Attitudes

Overall attitude

The Kruskal–Wallis test confirmed a statistically significant change in the attitude of the subjects before and after the education in medical genetics ($P < 0.001$). Post-hoc analysis found that the fifth and sixth years after education had a statistically significantly more positive attitude compared to students of the fifth year before education (all $P < 0.05$). The median overall attitude for fifth-year respondents before education is 57 (IQR 52–60), while for the same

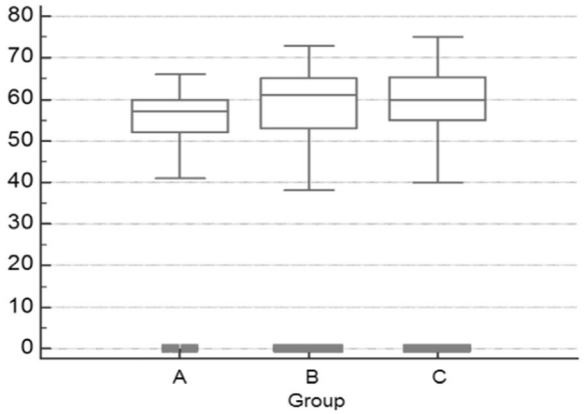

Fig. 3 Difference in overall attitude before and after medical genetics education shown by median, interquartile scattering and range. A: students of the fifth year before the completed course, B: students of the fifth year after the completed course and C: students of the sixth year after the completed course.

respondents after education it is 60 (IQR 55–65.25), and for sixth-year respondents 61 (IQR 53–65). The possible range of attitudes ranged from 19 to 95 (Fig. 3).

Attitudes towards genetic testing

A statistically significantly more positive change ($P < 0.001$) in attitudes towards genetic testing was observed between respondents in the fifth year before education and respondents in the fifth year after education and the sixth year, among whom there was no difference in results (Table 3). A statistically significant difference ($P < 0.001$) was observed in the change of attitude about one's own education and decision making. Students assessed whether they felt educated enough to interpret genetic testing findings, suggest drugs for pharmacogenomic testing, explain genetic concepts to the patient in a simple way and opinion on selling genetic tests online. The median attitude towards self-education in fifth-year students was 7 (IQR 5.75–9), while after education in fifth- and sixth-year students it was 12 (IQR–13). Sixth-year students were statistically significantly ($P < 0.001$) more likely to be able to explain simple genetic terms to the patient and to be sufficiently educated to interpret genetic testing findings than fifth-year students (before and after education). When assessing the decision-making attitude, students to a significantly greater extent ($P < 0.001$) noted that the doctor should not influence the patient's decisions, but the patient should make the final decision after the findings of genetic testing. After education, they felt that if the patient did not want to inform his family about the findings of genetic testing in which a diagnosis of severe hereditary disease was made, the development of which can be prevented by timely intervention, they would not do it instead ($P < 0.001$) in a statistically significantly higher percentage than fifth-year students (both before and after education). Attitude about genetic testing changed statistically significantly ($P < 0.001$), respondents after education felt that genetic testing should not be available to all individuals who want to be tested regardless of whether they have an indication for testing and that it should not be conducted on each new-born child, in contrast to the attitude of the respondents before education.

Discussion

The aim of examining and monitoring the change in knowledge and attitudes of medical students towards medical genetics before and after mandatory education in this study was to assess their basic literacy in medical genetics. In addition, although the results of previous research show the need for education at different levels of health care and in the general population, the impact of education on knowledge and attitudes has not been examined, which in this study, to our knowledge, was done for the first time. We found that knowledge was statistically significantly higher after education and that the change in knowledge was reflected in the statistically significant development of positive attitudes in fifth- and sixth-year students after education compared to fifth-year students before education ($P < 0.001$). The obtained results suggest that carefully designed, needs-based theoretical and practical education can significantly increase the self-confidence of future physicians and enhance the right decisions for the patient. Moreover, the results obtained by our research are similar to those in other studies that showed increased knowledge of genetics [10, 11, 15, 19, 20, 23, 24] and reported greater self-confidence of [24, 26] physicians after educational interventions, whereby guidelines for future work can be given.

Questionnaire

The questionnaire was designed according to the needs of the medical profession for medical genetics and as such can be of great importance for assessing the educational needs of medical students, trainees, family physicians and physicians who are not specialists of medical genetics. Also, the concept of the questionnaire implies the quantification of the change in the attitude of the respondents after the education as a direct consequence, and also as an element of assessing the quality of the provided education. The results of previous research show a need for better education of medical students as most physicians and nurses who received genetic education in their undergraduate programme stated that this content is not applicable in clinical practice [20]. This inequality points to the importance of preparing the workforce to increase the confidence of health care delivery professionals [39–41]. Their lack of understanding of the current value of genetics and genomics in health care

Table 3 Students' attitudes towards genetic testing before and after education.

Question	Median (25–75 IQR)			*P*
	A	B	C	
I feel educated enough to interpret the results of genetic testing	1 (1–2)	3 (3–4)	4 (3–4)	<0.001[a,b]
I would recommend prenatal diagnosis pregnant women at risk only	3 (2–4)	3 (2–5)	3 (2–5)	0.862
Genetic diseases cannot be treated causally and should therefore not be diagnosed	1 (1–2.5)	1 (1–1)	1 (1–1)	0.358
I would not undergo genetic testing because I worry about the confidentiality of results	1 (1–2)	1 (1–2)	1 (1–2)	0.100
I would not recommend genetic testing to my patients because I worry about the confidentiality of results	1 (1–1)	1 (1–2)	1 (1–1)	0.056
Genetic testing should be available to all individuals who want to be tested regardless of whether they have an indication for testing	3 (2–4)	2 (1–3)	2 (1–3)	<0.001[a]
I would like to know if the disease I have is hereditary	5 (4–5)	4 (4–5)	5 (4–5)	0.061
As long as the disease is not treatable, I do not want to undergo genetic testing	2 (1–2)	2 (1–2)	1 (1–2)	0.443
I know for which drugs I need to suggest pharmacogenomic testing to a patient	1 (1–2)	4 (3–4)	4 (3–4)	<0.001[a]
All women should undergo some of the available tests in prenatal diagnostics	2 (2–3)	2 (1–3)	2 (1–4)	0.365
I think it is good that genetic tests are sold on the internet because in that way they are easily available to physicians and patients	3 (1–3)	1 (1–1.25)	1 (1–2)	<0.001[a]
Genetic testing should be performed on every new-born child	3 (2–4)	2 (1–3)	1 (1–3)	<0.001[a]
Physicians should have an impact on patient decisions after the results of genetic testing	3 (3–4)	2 (1–3)	2 (1–3)	<0.001[a]
Patients should be able to make decisions on their own after the results of genetic testing	3 (2–4)	4 (3–5)	4 (3–5)	<0.001[a]
If a patient does not want to inform their family about their results of genetic testing that confirm the diagnosis of a severe hereditary disorder which can be prevented by timely intervention, I would do it instead of them	3 (2–3)	2 (1–3)	1 (1–2)	<0.001[a,b]
I find that I can easily explain professional genetic terms to a patient	2 (2–3)	4 (3–4)	4 (4–4)	<0.001[a,b]
I think that the future of medicine is in genetic testing	4 (3–4)	4 (3–5)	4 (3–4)	0.119
One should not interfere in genetics	1 (1–2)	2 (1–2)	2 (1–2)	0.941
I oppose genetic testing	1 (1–1)	1 (1–1)	1 (1–1)	0.660

A: students of the fifth year before the completed course, B: students of the fifth year after the completed course and C: students of the sixth year after the completed course.

[a]A vs BC.

[b]AB vs C.

represents a barrier that limits the potential benefits to patients [40]. However, all participants considered important to include the teaching of genetics in undergraduate programmes and believed in the potential of its application in clinical practice. Considering that our education was developed in accordance with Core Competences of the European Society of Human Genetics, our research points to the key role of proper needs-based education of students so that obtained knowledge can be applied in practice. The increased self-confidence visible from the results of our research will most likely be reflected in security in informing and making decisions important for the patient.

Knowledge about medical genetics

Previous studies on genetic education and understanding of genetics continuously indicate that the public, more specifically student groups, have low knowledge of genetics [6]. An increasing number of health care users are able to encounter new genetic knowledge and discoveries that offer a new type of decision making. How physicians use these new insights and make decisions about genetic risk will depend in part on their knowledge and attitudes about medical genetics [42]. Respondents support the use of genetic information to improve disease diagnosis and to help understand the cause of the disease; however, patients also take a critical view of certain aspects of testing and genetic information. Although there was a deficit in certain areas in students in this study, a relatively good level of knowledge about basic genetics was observed before education, and education directly affected the pre-existing deficits and increased specific knowledge about medical genetics, raising students' self-confidence.

It is interesting to note that compared with students in the fifth year after education, students in the sixth year after education had more knowledge about tumour heredity, foetal hydantoin syndrome, prenatal manifestation of genetic diseases and that the terms malformations and congenital anomalies are not synonymous, which can probably be explained by the fact that the sixth-year students had classes in gynecology and obstetrics course in parallel. Therefore, they

had the opportunity to further enrich their knowledge about genetic disorders and diseases that occur prenatally or at birth.

Education about genetic testing and certain genetic disorders through the course Medical Genetics resulted in a statistically significant change in knowledge about genetic testing and how different changes in one gene can cause different diseases. Issues related to general ethical principles, that is, the right of a person to refuse genetic testing, referral of patients by specialists and ordering a test without his knowledge were in a high percentage accurately resolved even before education, which indicates compliance with the code of ethics of doctors and patients, and shows that students (future physicians) respect their patients and colleagues. Also, it was shown that the knowledge of students in the fifth and sixth years after education is consistent, that is, after education there is no difference in direct and indirect knowledge in students. This indicates that the knowledge acquired in the course is not learned only for tests, but remains in long-term memory even after passing the final exam.

Attitudes about medical genetics

Previous research has shown that physicians do not conduct genetic testing and counselling sufficiently and it is considered that appropriate education would enhance the self-confidence and positive attitude of physicians, which would result in greater use of testing options [21, 26, 34].

Our research confirmed a statistically significant change in the attitude of respondents before and after education in medical genetics ($P < 0.001$). We found that the fifth and sixth years after education had a statistically significantly more positive attitude compared to students in the fifth year before education. Through education, students achieved a more positive attitude, which is reflected in their greater willingness to work directly with patients and a more positive view of their own education. The positive correlation between the amount of education in medical genetics and self-confidence in performing genetic services confirms the value of providing quality education [43]. Selected statements assessing the attitudes of respondents confirm that knowledge of the basics of medical genetics is needed, as well as skills for applying knowledge in practice. Consequently, after education the increase in knowledge can be reflected through greater self-confidence of students and the ability to clearly convey information about the disorder, provide quality care and respect autonomy and the patient's right to make decisions about their own treatment.

Conclusions

We determined the levels of knowledge and attitudes towards medical genetics in medical students at the Medical Faculty in Rijeka, Croatia, and confirmed that education from the mandatory course Medical Genetics has a statistically significant effect on their change. Specifically, the importance of our research was emphasised by demonstrating that needs-based education not only increases the knowledge of medical students, but also the attitudes and self-confidence that proved to be crucial in presenting a professional attitude and making the right decisions. Furthermore, by gaining more knowledge, students recognised the important role of physicians who are not medical genetics specialists in treatment of a patient with a genetic disorder and a medical geneticist in the role of a professional who provides lifelong care for the patient. Finally, the possibility of using a validated questionnaire for medical profession in assessing the need for education in medical genetics offers the opportunity to design future education based on actual needs of the healthcare community, which would instruct physicians how to identify and organise care for patients with genetic disorders.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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