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Original article

Knowledge and attitudes regarding genetic testing among Jordanians: An approach towards genomic medicine

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ABSTRACT

Background: The twenty first century can be called the genomic era referring to the rapid development of genetics, and the beginning of genomic medicine. An initial step towards genomic medicine is to evaluate the knowledge and attitude towards genetic testing among different populations. The aims of this study were to assess the genetic knowledge and attitude towards genetic testing among the Jordanian population and patients with immune diseases. In addition, we evaluated the association between knowledge, attitude and several demographic factors of the population.

Methods: This study was performed using an online questionnaire that was distributed to respondents from different regions of Jordan.

Results: A total of 1149 participants were recruited from the Jordanian population. Overall factual genetic knowledge of the participants was good (65.4%), with education level, working or studying in a health-related field and household average monthly income being significant predictors of factual knowledge scores ($P = 0.03$, $P < 0.001$ and $P < 0.001$, respectively). However, factual knowledge results revealed that scores of questions related to diseases were significantly higher than scores of gene-related scientific facts ($P < 0.01$). Participants of our study reported to have low perceived knowledge on medical uses (39.5%) and social consequences (23.9%) of genetic testing. Regarding the participants' attitudes, favorable attitudes towards genetic testing were prevailing (91.5%). Favorable attitudes were more prominent among higher educated participants, and participants with higher scores of factual knowledge.

Conclusion: Despite the fact that our Jordanian-based study revealed a good level of genetic knowledge as well as a favorable attitude towards genetic testing, we realized an imbalance of knowledge between gene-related scientific facts and disease-related concepts as well as between factual and perceived genetic knowledge, which indicates the necessity of increasing the awareness about genetic testing in order to ensure that individuals can take informed decisions that help in the employment of personalized medicine.

1. Introduction

During recent decades, the completion of the human genome project and new technological advances in the field of human genetics have led to an improvement in medical applications (Lappalainen et al., 2019). Genetic testing is used for several purposes such as carrier testing in order to detect a mutation or genetic variation in the DNA that might be inherited to the offspring of a person (Katsanis and Katsanis, 2013). DNA-testing allows screening of the human genome for genetic polymorphisms that associate with disease which in turn has led to the identification of various risk genes that increase the susceptibility to genetic diseases (Gregersen and Olsson, 2009; Katsanis and Katsanis, 2013). In addition, genetic testing has also become essential for confirmation of the clinical diagnosis of several autoimmune disorders (Schnappauf and Aksentijevich, 2019; Tobón et al., 2012). Several autoimmune diseases like Type 1 Diabetes (T1D), Rheumatoid Arthritis (RA), Systemic Lupus Erythematous (SLE) are known to have a genetic cause, in addition to environmental factors (Pociot and Lernmark, 2016; Teruel and Alarcón-Riquelme, 2016). Prediction of several autoimmune disorders like T1D, is done by

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analyzing genetic susceptibility factors of patients as HLA- DR/DQ alleles have been shown to be significantly associated with susceptibility to T1D (Khdair et al., 2020). Genetic and environmental factors are also assumed to play a key role in the development of many hypersensitivity disorders like Asthma and allergies to specific drugs and food so genetic testing can also be used to predict an individual's reaction to a certain drug or food (Abu-Dayyeh et al., 2020; Karlin and Phillips, 2014).

The incidence of genetic diseases among Arab populations "including Jordanians" is relatively high, which can be explained most probably by the high prevalence of consanguineous marriage (Hamamy et al., 2005; Tadmouri et al., 2009). As the prevalence of genetic disorders is increasing, a mandatory genetic premarital test for the early detection or prevention of β-thalassemia was implemented by the health ministry of Jordan in 2004 (Hamamy et al., 2007).

However, to understand the significance of DNA-testing for prediagnosis of genetic diseases, individuals require adequate genetic knowledge and a positive attitude towards genetic testing. According to previous studies, genetic literacy can affect public attitudes and understanding of genomic risk information (Lea et al., 2011). Many studies, in different populations, investigated knowledge of genes and attitudes towards genetic testing (Calsbeek et al., 2007; Hashemi-Soteh et al., 2019; Jallinoja and Aro, 1999; Morren et al., 2007; Olwi et al., 2016).

Since the importance of genetic testing is becoming evident worldwide and the new approach in genetics towards personalized medicine is to deal with patients according to their genetic profile, DNA-tests are becoming essential. Better genetic knowledge and a more positive attitude towards genetic testing will enable people to make informed decisions regarding different lifestyle choices based on their genetic profile. Assessing the population's knowledge and attitudes towards genetic testing is indeed essential for developing better strategies for making genetic testing more familiar and acceptable by the public in order to help in the prevention of genetic disorders. In addition, societies will be better prepared to establish strategies for ethical and rational distribution of benefits resulting from genetic sciences (Chapman et al., 2019). The aim of this study is to assess the knowledge and attitude towards genetic testing of the Jordanian population in general. It analyzes the association between knowledge, attitude and several demographic factors. In addition, since genetic testing is also needed to confirm clinical diagnosis of several immune diseases, this study also evaluates the knowledge and attitude of patients with immune diseases and how it compares to that of the general Jordanian population.

2. Materials and methods

2.1. Sample recruitment

The survey of this study was conducted online using google forms (supplementary file 1 for survey questions in Arabic) from September 2020 to October 2020. An ethical approval was granted from the IRB of Al-Zaytoonah University of Jordan. The online questionnaire was distributed using different generic social media platforms dedicated for Jordan in general in addition to other platforms targeting different Jordanian cities to ensure better representation of different segments of the Jordanian population. The inclusion criteria for the study was being a Jordanian national between 18 and 70 years old. Questions about age and nationality were included in the survey to ensure that all the participants met the inclusion criteria. The sample size that was required to achieve a representative sample of Jordanian population was calculated according to the confidence interval (CI) to be 95% and the margin of error to be <4% (Rao and Kish, 1969). The outcome of this calculation revealed that 600 responses should be recruited. A total of 1149 respondents from different regions of Jordan, mainly Amman, Irbid, and Zarqa took part in the questionnaire. The data of the participants were collected and analyzed anonymously. The population sample was separated into three groups according to their answer to specific questions: (i) The group that has no immune diseases (no hypersensitivity and autoimmune diseases) was designated as the "healthy" group, (ii) The hypersensitivity group which includes all the respondents who have food or drug allergy, hay-fever, asthma, eczema or urticaria, (iii) The autoimmune disease group which includes the respondents diagnosed with autoimmune diseases such as T1D, SLE, RA, Multiple sclerosis (MS), Psoriasis, and Hashimoto's Disease.

2.2. Questionnaire

The questionnaire started with an introductory section to describe the purpose and the aim of this study, without providing any information on genetics and genetic testing. After reviewing the related studies in the literature, 50 close-ended questions were included in the survey (Calsbeek et al., 2007; Haga et al., 2013; Jallinoja and Aro, 1999; Morren et al., 2007). However, some of the questions were developed by the research team of this study. All the questions were translated from English to Arabic through the forward–backward-forward technique (Beaton et al., 2000).

The whole content of the survey was reviewed by 5 specialists from the field and classified into four sections:

(1) Demographic characteristics of the participants; this section consists of 10 statements developed by the research team of this study (Table 1).
(2) Factual genetic knowledge; this section includes 16 questions that were implemented from similar studies to evaluate the actual knowledge about cells, genes, chromosomes, disease, the body and the association between them (Jallinoja and Aro, 1999) (Table 2). The answers were: Yes, No, or I do not know. Factual genetic knowledge was scored by granting one point for each correct answer with the highest possible score being sixteen.
(3) Perceived knowledge of genetics; 11 questions were used in this section. In responding to these questions, the participants are expected to estimate their own level of knowledge on the medical uses and the social consequences of DNA testing; , The answers were: sufficient knowledge, little but not sufficient knowledge, or no knowledge (Fig. 1, Fig. 2) (Morren et al., 2007). Perceived knowledge was scored as 0 = no knowledge, 1 = little but not sufficient knowledge, 2 = sufficient knowledge. Accordingly, the highest possible score for total perceived knowledge, perceived knowledge on medical uses and perceived knowledge on social consequences were 22, 10, 12, respectively.
(4) Attitudes towards genetic testing; 13 statements were used to measure the attitudes towards genetic testing: favorable attitude (6 statements on the pros of genetic testing; higher scores in this factor indicates a more favorable "positive" attitude towards genetic testing) and reserved attitude (7 statements on the cons of genetic testing; higher scores in this factor indicates a more reserved "negative" attitude towards genetic testing) and 3 scales were used: Agree, Disagree, and don't know (Table 5) (Morren et al., 2007). Attitudes towards genetic testing were scored as 1 = Disagree, 2 = don't know, 3 = Agree. Thus, the highest possible score for favorable and reserved attitude were 18 and 21, respectively. Conversely, the lowest possible score for favorable and reserved attitude were 6 and 7, respectively. The scores

Table 1
Sample demographics and characteristics (n = 1149) and the general population.

Variables		*N* (Frequency %)	*General population (%)*†	*P-value*
Age	18–29	344 (29.9)	37.75	<0.01
	30–39	347 (30.2)	24.33	
	40–49	293 (25.5)	17.62	
	50–59	109 (9.5)	10.57	
	60–70	56 (4.9)	5.23	
Sex	Female	829 (72.1)	47.06	<0.01
	Male	320 (27.9)	52.94	
Marital status	Not married	411 (35.8)	44.5	<0.01
	Married	738 (64.2)	55.5	
Education level	Primary education	8 (0.7)	N/A	
	High school	42 (3.7)		
	Diploma	84 (7.3)		
	Bachelor's degree	699 (60.8)		
	Postgraduate	316 (27.5)		
Studying/working in a health-related field	Yes	210 (18.3)	N/A	
	No	939 (81.7)		
Household average monthly income (JD)	<300	260 (22.6)	N/A	
	300–800	498 (43.3)		
	801–2000	261 (22.7)		
	>2000	130 (11.3)		
Health status	Hypersensitivity disorders	150 (13.1)		
	Autoimmune diseases	104 (9.1)		
	Healthy	855 (74.4)		
First degree relatives with autoimmune or chronic diseases	Yes	595 (51.8)		
	No	554 (48.2)		
Have you ever had information about genetics and genetic testing?	Yes	390 (33.9)		
	No	759 (66.1)		
Preferred source of information about genetics and genetics testing	Healthcare providers	377 (32.8)		
	Family, friends, or relatives	15 (1.3)		
	Specialized centers	333 (29)		
	Scientific brochures or online websites	338 (29.4)		
	Media/TV/Magazines	25 (2.2)		
	Unsure	61 (5.3)		

Abbreviations: Jordanian Dinar (JD).
†(Department of Statistics [Jordan] and ICF, 2019; Department of Statistics, 2019).

Table 2
Factual Genetic Knowledge of the total sample, healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases (frequencies and % of participants with a correct answer).

	Total sample *n = 1149 (%)*	Healthy *n = 855 (%)*	Hypersensitivity disorders *n = 150 (%)*	Autoimmune diseases *n = 104 (%)*
Q1-Q11 Gene-related scientific facts				
1. One can see a gene with the naked eye. (not correct)	929 (80.9)	690 (80.7)	122 (81.3)	79 (76)
2. A gene is a disease. (not correct)	986 (85.8)	737 (86.2)	128 (85.3)	80 (76.9)
3. A gene is a molecule that controls hereditary characteristics. (correct)	1062 (92.4)	789 (92.3)	140 (93.3)	90 (86.5)
4. Genes are inside cells. (correct)	866 (75.4)	649 (75.9)	112 (74.7)	72 (69.2)
5. A gene is a piece of DNA. (correct)	822 (71.5)	599 (70.1)	119 (79.3)	69 (66.3)
6. A gene is a cell. (not correct)	728 (63.4)	534 (62.5)	99 (66)	64 (61.5)
7. A gene is a part of a chromosome. (correct)	781 (68)	576 (67.4)	103 (68.7)	65 (62.5)
8. Different body parts include different genes. (not correct)	351 (30.5)	277 (32.4)	42 (28)	24 (23.1)
9. Genes are bigger than chromosomes. (not correct)	548 (47.7)	399 (46.7)	78 (52)	43 (41.3)
10. The genotype is not susceptible to human intervention. (correct)	436 (37.9)	330 (38.6)	57 (38)	39 (37.5)
11. It has been estimated that a person has about 22,000 genes. (correct)	209 (18.2)	149 (17.4)	23 (15.3)	27 (26)
Q12-Q16 disease-related concepts				
12. Healthy parents can have a child with a hereditary disease. (correct)	938 (81.6)	689 (80.6)	127 (84.7)	79 (76)
13. The onset of certain diseases is due to genes, environment and lifestyle. (correct)	913 (79.5)	675 (78.9)	119 (79.3)	78 (75)
14. The carrier of a disease gene may be completely healthy. (correct)	984 (85.6)	729 (85.3)	132 (88)	84 (80.8)
15. All serious diseases are hereditary. (not correct)	894 (77.8)	667 (78)	117 (78)	73 (70.2)
16. The child of a disease gene carrier is always also a carrier of the same disease gene. (not correct)	568 (49.4)	434 (50.8)	70 (46.7)	52 (50)

of factual genetic knowledge, perceived knowledge and attitudes toward genetic testing were converted to percentages by dividing the scores by the maximum possible score and multiplying by 100.

A pilot study was conducted with a sample of 30 participants, 12 individuals were from the healthcare system field and the others were from the public. Minor modification was performed to the questionnaire according to the feedback, in order to be delivered and answered by the public. A test- retest reliability evaluation was done as 60 respondents were asked to retake the questionnaire after 14 days. The participants of both pilot and test–retest study were excluded from the analyzed data and their data are not presented in the present study.

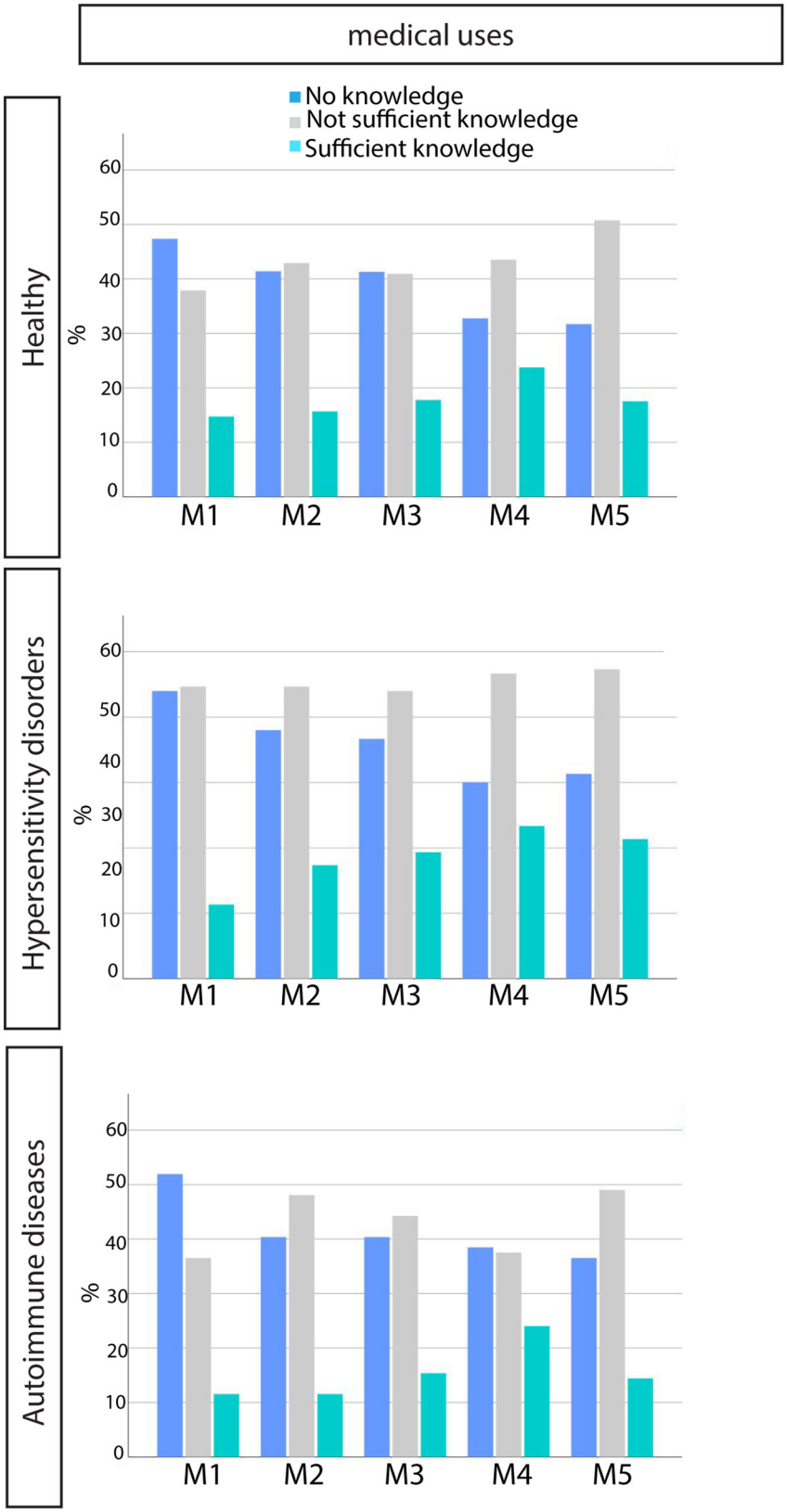

Fig. 1. Perceived genetic knowledge on medical uses of the healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases (frequency %). Abbreviations: M1; The possibilities and risks of gene therapy, M2; The significance of DNA testing for my relatives, M3; The significance of DNA testing for my offspring, M4; The possibility to use genetic knowledge to prevent or treat a disorder, M5; The possibility of early detection of certain disorders using DNA-testing.

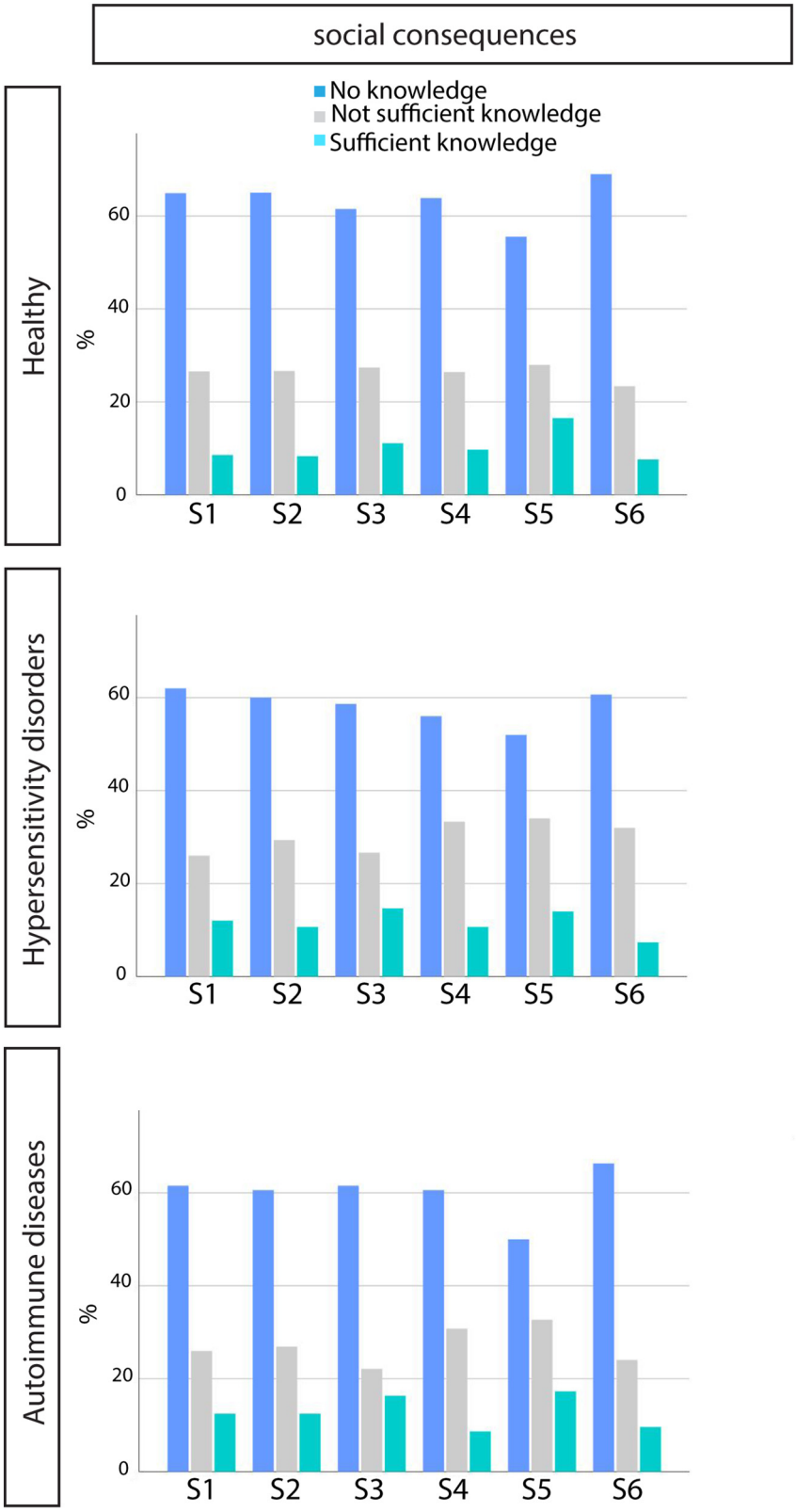

Fig. 2. Perceived genetic knowledge on social consequences of the healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases (frequency %).Abbreviations: S1; The consequences of DNA-testing for my work, S2; The consequences of DNA-testing for taking out insurance, S3; The rights of third parties to inquire about the results of a DNA-test, S4; The consequences of DNA-testing for my daily life, S5; Your rights to refuse DNA-testing, S6; Your own possibilities to apply for a DNA-test.

2.3. Data analysis

Data analysis were done using SPSS version 25. Categorical data were presented as frequencies and percentages (%), while continuous data were represented as mean and standard deviation (SD). When data are available, the characteristics of the current sample were compared with the characteristics of the general Jordanian population (Department of Statistics [Jordan] and ICF, 2019; Department of Statistics, 2019) using Chi-square for multinomial variables and binomial test for dichotomous variables.

The participants were divided into two groups (high vs low) according to their factual knowledge score, total perceived knowledge scores, perceived knowledge on medical field scores and perceived knowledge on social field scores. Participants who scored above the total sample mean were included in the "high" groups while those who scored below the mean were included in the "low" groups.

Binary logistical regression models were constructed to evaluate the variables associated with factual genetic knowledge, perceived genetic knowledge, as well as favorable and reserved attitudes towards genetic testing. These models included the following independent variables: Age groups (as shown in Table 1), Education level (Primary education "grades 1 to 10", Secondary education "grades 11 and 12", Diploma "2 years in community college after high school", Bachelor degree, Postgraduate "Master's degree and PhD"), sex, marital status, Job (Health-related jobs which include those who are studying or working in the following fields "Pharmacy, Nursing, Medicine and other Biomedical sciences" while the rest were categorized separately as Non-health related jobs), Household average monthly income in Jordanian dinars (JD). Spearman's test was conducted to evaluate the correlations between independent variables that were included in the regression models.

Cronbach's alpha and Intra class correlations (ICC) coefficient were calculated to measure internal consistency and test–retest reliability and the results of the analysis are included in the results section.

3. Results

3.1. Demographic characteristics of the sample

As shown in Table 1, this questionnaire was completed by 1149 participants; the majority (72.1%) of them were females, one-third of them were between 18 and 29 years (29.9%), one-third were between 30 and 39 years (30.2%), and most of them were married (64.2%). More than half of the participants (60.8%) had a bachelor's degree, 27.5% were postgraduates, and <1% had only primary education. About one fifth of the participants were studying/working in a health-related field (18.3%). The participants' household average monthly income varied from <300 JD (22.6%) to more than 2000 JD (11.3%).

Binomial/Chi square tests were conducted to compare the characteristics of the study sample with the Jordanian general population (with available data) (Department of Statistics [Jordan] and ICF, 2019; Department of Statistics, 2019) and the results indicated that there were significant differences in age distribution, marital status, and sex (p value < 0.01).

Most of the participants were healthy (74.4% had no immune diseases), 13.1% of them had hypersensitivity disorders, and 9.1% had an autoimmune disease, while more than half of them (51.8%) had a first degree relative with a chronic or autoimmune disease. Almost two-thirds of the participants (66.1%) never had information about genetics and genetic testing, and the most replied that the preferred source of information about genetics was healthcare providers (32.8%), followed by scientific brochures or online websites (29.4), and specialized centers (29%).

3.2. Factual genetic knowledge

Table 2 represents the factual genetic knowledge of the total sample, healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases. Q1 to Q11 measure the knowledge of participants regarding gene-related scientific facts while Q12 to Q16 measure diseases-related concepts.

The most commonly known information about genetics among all the studied groups was the knowledge of gene as a molecule that controls the hereditary characteristics (92.4%). On the other hand, the least correct answer was for the number of genes that a person has, as less than a third of the participants in all studied groups agreed that the estimated number is about 22,000 genes (18.2%). Factual knowledge results revealed high knowledge of disease-related facts while knowledge of gene-related scientific facts was relatively low. Disease-related knowledge and gene-related knowledge mean percentages were 74.8% and 61%, respectively and according to Wilcoxon test this difference was shown to be significant ($P < 0.01$).

The participants were divided into two groups according to their knowledge score; the high-knowledge group included participants that scored more than the total sample score mean (mean = 11; and score percentage mean was 65.4%, SD = 21.9%) and the low-knowledge group included participants that scored below the total sample score mean.

Prior to conducting the binary logistic regression, the correlations between independent variables were examined using Spearman's test and the results indicated significant correlation between different sample characteristics. However, only one moderate correlation was found (between age and marital status ($r = 0.52$, p-value < 0.01), while the rest were weak ($r < 0.5$) or negligible correlations ($r < 0.3$).

The results of binary logistic regression analysis of factual knowledge of genes are shown in Table 3. The results revealed that different sample characteristics were significant contributors to the participants' knowledge level. The first factor was education level, as being in the primary education group significantly decreased the odds of being in the high-knowledge group when compared to postgraduate group (OR = 0.10, P = 0.03). The second factor was the work or study field. Working in or studying a health-related field significantly increased the odds of being knowledgeable compared to a non-health related field (OR = 7.87, $P < 0.001$). Lastly, having a household average monthly income of 2000 JD or more significantly increased the odds of being knowledgeable compared to having an income of 300 JD or less (OR = 2.7, $P < 0.001$).

3.3. Perceived genetic knowledge

Figs. 1 and 2 show the perceived knowledge of the studied groups (healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases) on both medical uses (Fig. 1) and social consequences (Fig. 2) of genetic testing. The scales reliability was high as Cronbach's alpha was 0.94 for the total perceived knowledge, 0.9 for perceived knowledge on medical uses, and 0.93 for perceived knowledge on social consequences. In general, participants reported low perceived genetic knowledge on medical uses (total sample score mean = 3.95, SD = 3.04; and score percentage mean was 39.5%, SD = 30.37%). As well, participants also had low perceived genetic knowledge regarding social consequences (total sample score mean = 2.87, SD = 3.45; and score percentage mean was 23.9%, SD = 29%).

Table 3
Binary regression Analysis of Factual Genetic Knowledge.

	B	S.E.	Wald	Df	*P*	Odds Ratio	95% CI for Odds Ratio (B)	
							Lower	Upper
Age (ref. group: 18–29)								
(30–39)	0.02	0.21	0.01	1.00	0.93	1.02	0.68	1.52
(40–49)	−0.10	0.22	0.22	1.00	0.64	0.90	0.58	1.40
(50–59)	−0.27	0.28	0.96	1.00	0.33	0.76	0.44	1.31
(60–70)	0.30	0.35	0.75	1.00	0.39	1.35	0.68	2.67
Sex (ref. group: males)	0.29	0.15	3.75	1.00	0.05	1.34	1.00	1.80
Females								
Marital status	0.17	0.17	0.99	1.00	0.32	1.18	0.85	1.64
(ref. group: married)								
Not married								
Education level (ref. group: postgraduate)								
Primary school	−2.33	1.10	4.49	1.00	**0.03**	0.10	0.01	0.84
High school	−0.58	0.36	2.70	1.00	0.10	0.56	0.28	1.12
Diploma	−0.50	0.27	3.51	1.00	0.06	0.61	0.36	1.02
Bachelor's degree	−0.24	0.16	2.38	1.00	0.12	0.79	0.58	1.07
Job	2.06	0.25	68.61	1.00	**<0.001**	7.87	4.83	12.83
(ref. group: *non-health related*)								
Health related jobs								
Household average monthly income (ref. group: very low income)								
Low income	−0.02	0.18	0.01	1.00	0.92	0.98	0.69	1.40
Moderate income	0.26	0.21	1.52	1.00	0.22	1.30	0.86	1.98
High income	0.99	0.28	12.55	1.00	**<0.001**	2.70	1.56	4.69
Hypersensitivity disorders (ref. group: "Do not have")	0.08	0.20	0.15	1.00	0.70	1.08	0.73	1.60
"Have"								
Autoimmune diseases	0.28	0.23	1.47	1.00	0.23	1.33	0.84	2.09
(ref. group: "Do not have")								
"Have"								

Abbreviations: B coefficient (B); Standard Error (SE); Wald chi-square test (Wald); degrees of freedom (df); p-value (p); Confidence Interval (CI). Reference (ref.). Bold indicates significance at P < 0.05.

For the perceived knowledge on medical uses, the statement with the mostly reported "sufficient knowledge" in all the subgroups was "the possibility to use genetic knowledge to prevent or treat a disease" (23.7%(while the statement with the mostly reported "no knowledge" was "the possibilities and risks of gene therapy" (47.8%) for the total sample and in each subgroup. For the perceived knowledge on social consequences, the statements with the mostly reported "sufficient knowledge" in the total sample and in each group were "the rights to refuse DNA-testing" (16.6%) and "the rights of third parties to inquire about the results of a DNA-test" (11.8%). On the other hand, the statements with the mostly reported "no knowledge" were "Your own possibilities to apply for a DNA-test" (68.4%) and "the consequences of DNA-testing for taking out insurance" (64.6%) for the total sample and in each subgroup.

The participants were divided into two groups for each of the following: total perceived knowledge, perceived knowledge on medical uses and perceived knowledge on social consequences; the high-knowledge groups included participants who scored above the total sample mean in each category and the low-knowledge groups were those who scored below the mean in each category. The means for the total perceived knowledge, perceived knowledge on medical uses and perceived knowledge on social consequences were 6.82, 3.95 and 2.87, respectively.

The results of the binary logistical regression of perceived genetic knowledge are shown in Table 4. Work or study field had a significant contribution to the perceived knowledge in the total score, medical uses and social consequences (OR = 2.25, P < 0.01; OR = 2.98, P < 0.01; OR = 1.87, P < 0.01, respectively). So, working or studying in a health-related field significantly increased the odds of having higher perceived knowledge scores in the three scores compared to not working at or studying a health-related field. Also, those with high school, diploma, or bachelor's degree education have significantly lower odds of getting higher scores than those with a postgraduate degree. Low factual knowledge significantly decreased the odds of getting high total perceived-knowledge scores, perceived knowledge on medical uses, and perceived knowledge on social consequences (OR = 0.47, P < 0.01; OR = 0.42, P < 0.01; OR = 0.51, P < 0.01, respectively). Sex had a significant effect on the perceived knowledge on medical uses as females had higher odds of getting higher scores (OR = 1.40, P = 0.02). Lastly, age had a significant contribution to the odds of being the high-knowledge group in the perceived knowledge on social consequences, as being in the 30–39 years age group significantly decreased the odds of getting a high score when compared to 18–29 age group (OR = 0.64, P = 0.03).

3.4. Attitudes towards genetic testing

Table 5 shows the attitudes towards genetic testing in the total sample, healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases. The reliability scales were confirmed by Cronbach's alpha values as it was 0.8 for favorable attitudes and 0.74 for reserved attitudes.

In general, the total mean score percentage for favorable attitudes was high (91.5%; SD = 12.5). In all studied groups, most participants agreed that DNA research development is a positive medical progress (89.3%) and most participants think that the development of DNA research is hopeful for treating diseases (87.6%). The majority also approved of using DNA-testing for early detection of diseases (81.8%) and wanted to know if their diseases are hereditary (84.4%). A considerable percentage of the participants in all studied groups were willing to inform their siblings about the results of a DNA-test for a specific disease (72.9%) and, to a lesser degree, to inform their children about DNA-test results for a specific disease (63.6%). On the other hand, the total mean score percentage for reserved attitudes was 68.5% (SD = 14.9). A high percentage of the participants in all studied groups believed

Table 4
Binary Regression Analyses of Perceived Genetic Knowledge.

	Total perceived knowledge		Perceived knowledge on medical uses		Perceived knowledge on social consequences	
	P	Odds Ratio	*P*	Odds Ratio	*P*	Odds Ratio
Age (ref. group: 18–29)						
(30–39)	0.10	0.73	0.36	0.83	**0.03**	0.64
(40–49)	0.61	1.12	0.13	1.40	0.75	1.07
(50–59)	0.61	1.15	0.33	1.31	0.80	0.93
(60–70)	0.52	1.24	0.11	1.76	1.00	1.00
Sex (ref. group: males) *Females*	0.50	1.10	**0.02**	1.40	0.55	0.92
Marital status (ref. group: married) *Not married*	0.60	1.09	0.85	0.97	0.71	0.94
Education level (ref. group: postgraduate)						
Primary school	0.90	1.09	0.49	0.59	0.46	1.76
High school	**0.03**	0.45	**<0.01**	0.32	**0.04**	0.48
Diploma compared	**0.049**	0.59	**<0.01**	0.47	**0.03**	0.55
Bachelor's degree	**<0.01**	0.51	**<0.01**	0.54	**<0.01**	0.48
Job (ref. group: *non-health related job*) *Health related job*	**<0.01**	2.25	**<0.01**	2.98	**<0.01**	1.87
Household average monthly income (ref. group: very low income)						
Low income	0.22	0.81	**0.02**	0.65	0.69	0.93
Moderate income	0.52	0.88	0.21	0.77	0.41	0.84
High income	0.20	0.71	0.24	0.73	0.23	0.73
Hypersensitivity disorders (ref. group: "Do not have") *"Have"*	0.71	0.93	0.88	0.97	0.67	1.08
Autoimmune disease (ref. group: "Do not have") *"Have"*	0.93	0.98	0.94	0.99	0.41	1.20
Factual knowledge (ref. group: "high knowledge") *Low knowledge*	**<0.01**	0.47	**<0.01**	0.42	**<0.01**	0.51

Reference (ref.). Bold indicates significance at $p < 0.05$.

Table 5
Attitudes towards Genetic Testing of the total sample, healthy participants, patients with hypersensitivity disorders, and patients with autoimmune diseases (frequencies and % of participants that agree).

Favorable (% agree)	Total sample *n = 1149 (%)*	Healthy *n = 855 (%)*	Hypersensitivity disorders *n = 150 (%)*	Autoimmune diseases *n = 104 (%)*
1. I think the development of DNA research is hopeful for the treatment of diseases	1007 (87.6)	748 (87.5)	133 (88.7)	91 (87.5)
2. I think that the development of DNA research is a positive medical progress	1026 (89.3)	762 (89.1)	139 (92.7)	90 (86.5)
3. I approve of using DNA-testing for early detection of diseases	940 (81.8)	694 (81.2)	128 (85.3)	82 (78.8)
4. I would inform my siblings about the results of a DNA-test for a specific disease	838 (72.9)	607 (71)	117 (78)	81 (77.9)
5. I would inform my children about the results of a DNA-test for a specific disease	731 (63.6)	525 (61.4)	95 (63.3)	79 (76)
6. I want to know whether my disease is hereditary	970 (84.4)	718 (84)	130 (86.7)	90 (86.5)
Reserved (% agree)				
7. The possibility of a DNA-test will change one's future	873 (76)	644 (75.3)	123 (82)	78 (75)
8. I worry about the consequences of DNA-testing for being able to take out insurance	465 (40.5)	328 (38.4)	78 (52)	48 (46.2)
9. As long as a disease cannot be treated, I don't want a DNA-test	231 (20.1)	160 (18.7)	40 (26.7)	31 (29.8)
10. If I had a DNA-test done, my family need not know about the result	254 (22.1)	195 (22.8)	33 (22)	16 (15.4)
11. I worry about the consequences of DNA-testing for the chances of finding a job	298 (25.9)	220 (25.7)	48 (32)	24 (23.1)
12. I don't want a DNA-test to tell me that I am at risk for a certain disease	261 (22.7)	199 (23.3)	40 (26.7)	25 (24)
13. The idea of DNA-tests frightens me	258 (22.5)	191 (22.3)	49 (32.7)	20 (19.2)

that the possibility of a DNA-test would change one's future (76%). However, fewer numbers of participants in each studied group were worried about the consequences of DNA-testing for taking out insurance (40.5%) and the consequences of DNA-testing for the chances of finding a job (25.9%). Only about one fifth of the total sample did not want a DNA test if the tested disease is untreatable, and a similar percentage of participants (22.5%) were frightened by the DNA testing idea.

Table 6 shows the results of binary logistical regression analyses of favorable and reserved attitudes towards genetic testing. For the favorable attitude; sex, education level, factual knowledge, and perceived medical knowledge significantly contribute to the odds of having or not having a favorable attitude. Being a female significantly increased the odds of having a favorable attitude when compared to males (OR = 1.40, P = 0.03). Moreover, having a high school education significantly decreased the odds of having a favorable attitude compared to postgraduate degree holders (OR = 0.29, P < 0.001). For factual knowledge and perceived medical knowledge, similar findings were observed as having low scores significantly decreased the odds of having a favorable attitude (OR = 0.43, P < 0.001; OR = 0.64, P = 0.01, respectively). On the other hand, reserved attitudes have different significant contributors: age, having a hypersensitivity disorder, and perceived social knowledge. Being in the 60–70 years age group significantly decreased the odds of having a reserved attitude when compared to 18–29 years age group (OR = 0.36, P < 0.001). Also, patients

Table 6
Regression Analyses of Favorable and Reserved Attitudes towards Genetic Testing.

	Favorable attitude		Reserved attitude	
	P	Odds Ratio	*P*	Odds Ratio
Age (ref. group: 18–29)				
(30–39)	0.53	1.14	0.95	1.01
(40–49)	0.35	1.24	0.67	1.10
(50–59)	0.47	1.24	0.43	1.24
(60–70)	0.59	1.22	**<0.001**	0.36
Sex (ref. group: males)	**0.03**	1.40	0.61	1.08
Females				
Marital status (ref. group: married)	0.51	1.12	0.86	1.03
Not married				
Education level (ref. group: postgraduate)				
Primary school	0.25	0.40	0.92	0.93
High school	**<0.001**	0.29	0.09	0.54
Diploma	0.20	1.45	0.65	1.13
Bachelor's degree	0.84	0.97	0.22	1.20
Job (ref. group: *non-health related job*)	0.05	1.48	0.81	0.96
Health related job				
Household average monthly income (ref. group: very low income)				
Low income	0.83	1.04	0.53	0.90
Moderate income	0.06	1.51	0.62	1.10
High income	0.28	1.35	0.08	1.57
Hypersensitivity disorders (ref. group: "Do not have")	0.99	1.00	**0.01**	1.67
"Have"				
Autoimmune diseases (ref. group: "Do not have")	0.13	1.47	0.27	0.79
"Have"				
Factual knowledge (ref. group: "high knowledge")	**<0.001**	0.43	0.20	0.84
Low knowledge				
Perceived medical knowledge (ref. group: "high perceived knowledge")	**0.01**	0.64	0.22	1.20
Low perceived knowledge				
Perceived social knowledge (ref. group: "high perceived knowledge")	0.39	0.87	**0.02**	0.71
Low perceived knowledge				

Reference (ref.). Bold indicates significance at P < 0.05.

who suffer from hypersensitivity disorders have significantly higher odds of having a reserved attitude when compared to those who do not (OR = 1.67, P = 0.01). Lastly, having low perceived social knowledge significantly decreases the odds of having a reserved attitude (OR = 0.71, P = 0.02).

3.5. Test-retest reliability

Overall, ICC coefficient for factual knowledge, perceived medical knowledge, perceived social knowledge, favorable attitude and reserved attitude was (0.85, 0.81, 0.83, 0.95 and 0.87, respectively) indicating good test re-test reliability.

4. Discussion

A population's understanding and acceptance of gene testing plays a major role in the implementation of personalized medicine as well as in the early diagnosis of diseases (Bíró et al., 2020; Syurina et al., 2011). This study is based on evaluating the knowledge and attitude of the Jordanian population towards genetic testing.

4.1. Factual genetic knowledge

The genetic knowledge of the Jordanian population was assessed using a factual knowledge test about genes and their association with genetic disorders. In general, participants of our study had good genetic knowledge as the overall factual knowledge mean percentage was 65.4%. This score is aligned with a previous study in the Finnish population (63.5%) (Jallinoja and Aro, 1999), but is lower than the score of the U.S population (83.6%) (Haga et al., 2013). On the other hand, the Jordanian population score is higher than that of the Chinese population (59.2%) (Zhang et al., 2020) as well as the Dutch population (45.8%) (Calsbeek et al., 2007). However, factual knowledge results revealed high knowledge of disease-related facts while knowledge of gene-related scientific facts was relatively low (means were 74.8% and 61%, respectively). Furthermore, our study indicated a significant difference in knowledge between disease-related concepts and gene-related scientific facts (P < 0.01), which is in line with published findings done among different populations, despite the cultural differences and the variation in educational programs (Calsbeek et al., 2007; Haga et al., 2013; Jallinoja and Aro, 1999). This inconsistency may be attributed to increased reporting of the relation of genetics and diseases by media, which results in the public population being more familiar with disease-related concepts (Bates, 2005). Consistent with previous studies, a positive association was shown between higher education and higher scores of factual genetic knowledge (Calsbeek et al., 2007; Haga et al., 2013; Zhang et al., 2020). In addition, a higher score of factual genetic knowledge was reported in our study in participants with health-related education/ jobs as well as high-income households.

4.2. Perceived genetic knowledge

Participants of our study reported low perceived genetic knowledge (39.5% for medical uses and 23.9% for social consequences). These results are consistent with previous studies (Calsbeek

et al., 2007; Morren et al., 2007). One explanation for this might be that the public takes information about genetics from the media, which may result in inaccurate and incomplete information compared to other, more expert sources of information. (Park, 2001). In addition, the population may have the knowledge about cells, chromosomes, DNA and diseases but lack genetic literacy, which makes it difficult for them to translate genetic knowledge into practice (Lanie et al., 2004). Similar to previous studies, higher perceived genetic knowledge was found to be significantly associated with higher education levels (Calsbeek et al., 2007; Haga et al., 2013; Jallinoja and Aro, 1999; Morren et al., 2007).

4.3. Attitudes towards genetic testing

Our study also investigated public attitudes towards genetic testing. Our results revealed a positive attitude towards genetic testing as the total mean score percentage for favorable attitudes was 91.5%. Participants of our study had a more positive attitude than the U.S. population (87.7%) (Haga et al., 2013), the Dutch population (78%) (Calsbeek et al., 2007), as well as the Chinese population (77.1%) (Zhang et al., 2020). The higher scores in favorable attitudes in Jordan in comparison to other countries could be attributed to the national government campaigns (Hamamy et al., 2007). In addition, our results showed that higher educational levels, factual knowledge, perceived medical knowledge significantly contribute towards a favorable attitude. Similar findings were reported in previous studies (Calsbeek et al., 2007; Haga et al., 2013; Jallinjoa and Aro, 2000; Morren et al., 2007; Zhang et al., 2020). The main worries of the participants in our study were about the possibility of a DNA-test changing one's future (76%) and the consequences of DNA-testing on their insurance coverage (40.5%), which is a true concern because individuals with genetic and chronic diseases in Jordan as well as in other countries will be troubled getting insurance (Bélisle-Pipon et al., 2019).

4.4. Strengths and limitations

A strength of our study was that all the participants completed all the items of the survey without skipping any questions which expresses high awareness about the importance of genetics, immune diseases and genomics. The analysis indicated that the distribution of our sample was significantly different from the general Jordanian population in age distribution, marital status, and sex. This may be caused by the methodology of the current study which relied on online data collection, which may result in selection and recall biases. However, the impact of these biases could be reduced by the large sample size enrolled in the current study (1149 while the minimal statistical required sample size was 600). Thus, each subgroup was sufficiently represented in this study. Moreover, a possible explanation for the high percentage of female respondents (72.1%) is that females are at higher risk of developing immune diseases than males (Angum et al., 2020) and thus show more interest in immunogenetics and genomics. Furthermore, although the age distribution of the study sample was not a perfect representation of the general population, both are positively skewed with higher percentages in the younger age groups. Another limitation of this study was that the patient groups with hypersensitivity disorders and autoimmune diseases were classified according to the participant's self-reporting and were not confirmed independently by a healthcare provider. Finally, although the online methodology may produce the previously mentioned biases, it provides a safe and private environment for the respondents to answer accurately and honestly.

5. Conclusions

In conclusion, most of our Jordanian-based study population had a relatively good factual knowledge and a positive attitude towards genetic testing. Nevertheless, respondents reported low perceived knowledge about medical uses and social consequences of DNA testing. So, our study suggests that there is a discordance between factual genetic knowledge and perceived knowledge, which indicates that more efforts are needed to increase the awareness of the population. Furthermore, patients with hypersensitivity disorders and patients with autoimmune diseases were not more knowledgeable regarding genetic testing than the rest of the population (those with no immune diseases), even though these diseases are partly of genetic cause. Our results revealed that the patients' knowledge that their illness could be hereditary was not of added value for increasing the genetic knowledge and attitude of the patients. Therefore, health care providers and government campaigns should increase the awareness of patients about the role of genetic factors in the development of some immune diseases.

However, some degree of knowledge about genetics and genetic testing is needed in the population, especially in individuals suffering from genetic disorders, as lack of knowledge may influence people's decisions regarding genetic testing. This may indeed slow down the process of disease diagnosis and may make it difficult to prevent the quick progress of some diseases which might even make later treatments more complicated and costly (Andrus and Roth, 2002). In addition, individuals who are susceptible to developing genetic disorders, due to family history of hereditary diseases, are more affected by the lack of genetic knowledge than those who are not at risk. In summary, an individuals' understanding of personal genomic risk to a certain disorder affects the health behaviour of the individual thus affecting the employment of personalized medicine.

We recommend the application of optimized educational and health care system interventions in order to ensure that individuals can take informed decisions regarding health-related, particularly gene testing-related issues therefore enhancing the development of personalized medicine. The government plays a key role in increasing the awareness of the population by the application of national campaigns, in addition to developing policies to protect patient's rights as well as providing a system to oversight gene tests. On the other hand, educating health care providers about genetic tests to be able to provide the patients with adequate counselling. This could in turn raise patients' confidence in the results of gene tests and security that the test results cannot be used to their disadvantage by employers or insurers. Finally, our study showed a more favorable attitude towards genetic testing which indicates willingness to improve the health outcome towards personalized medicine.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sjbs.2021.04.004.

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