Journal of Clinical and Translational Science

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Integrating mRNA vaccines into the attitudes toward genomics and precision medicine scale: A validation study with a sample of 4939 adults in the USA

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Brief Report

Cite this article: Harris JK, Solomon ED, Baldwin K, Baker LL, Chin EG, and DuBois JM. Integrating mRNA vaccines into the attitudes toward genomics and precision medicine scale: A validation study with a sample of 4939 adults in the USA. *Journal of Clinical and Translational Science* **9**: e60, 1–7. doi: 10.1017/cts.2025.38

Received: 19 August 2024
Revised: 22 January 2025
Accepted: 18 February 2025

Keywords:
Genomics; precision medicine; religion; mRNA; factor analysis

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Abstract

The attitudes toward genomics and precision medicine (AGPM) measure examines attitudes toward activities such as genetic testing, gene editing, and biobanking. This is a useful tool for research on the ethical, legal, and social implications of genomics, a major program within the National Institutes of Health. We updated the AGPM to explore controversies over mRNA vaccines. This brief report examines the factor structure of the updated AGPM using a sample of 4939 adults in the USA. The updated AGPM's seven factors include health benefits, knowledge benefits, and concerns about the sacredness of life, privacy, gene editing, mRNA vaccines, and social justice.

Introduction

Public health genomics and precision medicine are a diverse collection of activities aimed at diagnosing disorders, tailoring treatments to individuals' genome, reducing hereditary diseases, and advancing medical science [1]. Such activities include genetic testing (pre- and postnatal), gene editing (e.g., using CRISPR), stem cell research, and gathering data on health environments and behavior. During the recent pandemic, several COVID-19 vaccines adopted a relatively new approach to providing people with immunity using messenger RNA [2]. While these mRNA vaccines were highly effective, they were also highly controversial in some circles [3].

Genomics and precision medicine (GPM) has generated a wide array of ethical and social issues. When the US Congress established the National Human Genome Research Institute (NHGRI), it mandated that 3% of its budget be spent exploring "ethical, social, and legal implications" (ELSI) of genomics [4]. The ELSI program has produced an extensive body of literature, research tools, and policy recommendations, which are now housed on the ELSIhub.org website.

In 2021, we published in this journal the "Attitudes toward Genomics and Precision Medicine" (AGPM) measure [5]. The AGPM describes six precision medicine activities: (a) postnatal genetic testing, (b) collecting information on lifestyle and environment, (c) storing and sharing biospecimens and health data, (d) genome editing, (e) stem cell therapy and research, and (f) prenatal genetic testing. Each activity is followed by a series of statements that express either a perceived benefit or a concern with the GPM activity.

In 2023, we used revised AGPM in a large study ($n = 4939$) that examined how religion shapes attitudes toward GPM. A 2023 Gallup survey found 82% of US adults were religious or spiritual [6], while the Pew Research Center reported 90% of US adults believe in God as described in the Bible or a higher power or spiritual force [7]. More than half (53%) of US adults are involved in a religious or spiritual community [8]. Research suggests religious practice is correlated with concerns about GPM, including genetic testing, gene editing, and stem cell therapies [9].

Given the widespread concern about COVID-19 vaccines in some sectors of US society, we decided to revise the AGPM prior to use in our new study. We made 3 changes to the original the 38-item AGPM instrument: (1) we added the new mRNA activity with 4 items representing perceived benefits or concerns; (2) we cut the activity of collecting lifestyle and environmental information which raised no new concerns beyond those already raised with other activities; and (3) we added one overall support item per activity. The four items added about mRNA vaccines were: mRNA vaccines could protect my health; mRNA vaccines could protect the health of the most vulnerable people in society; I am concerned that mRNA vaccines might change human bodies in ways that are unknown; and I worry that people will be required to get mRNA vaccines.

Overall support items addressed all six activities, and each had the form, "I generally support the use of . . . " (e.g., genetic testing).

In this paper, we explore a revised factor structure of the new AGPM.v23. We aim not only to provide information on the AGPM.v23 but also to explore the challenges of developing a measure with items written to address two things simultaneously: specific GPM activities (such as prenatal genetic testing) and cross-cutting latent factors (such as embryo concerns or perceived benefits).

Materials and methods

We conducted an online survey to understand how religion influences attitudes toward GPM issues. We conducted the survey with US adults between February 6, 2023, and April 5, 2023. The survey took 30–45 minutes to complete and was administered using Qualtrics. In addition to the AGPM, survey items included a battery of measures examining variables, such as religious affiliation, frequency of attendance at services, personal prayer practices, and views of the body and human origin, and demographics, such as education and political affiliation. The AGPM items were measured on a 7-point Likert scale with the following options: 7 = strongly agree, 6 = agree, 5 = somewhat agree, 4 = neither agree nor disagree, 3 = somewhat disagree, 2 = disagree, and 1 = strongly disagree. The AGPM.v23 survey instrument may be requested at https://bioethicsresearch.org/research-services/testing-services/.

We used two survey panel companies, Prolific and Cloud Research, for participant recruitment. Participants from Prolific were representative of the US population in terms of age, race, and gender, and in the Cloud Research sample, we over-sampled for specific religious affiliations. After removing participants who did not pass preliminary quality checks, our final sample included 2999 from Prolific and 1940 from Cloud Research, for a total of 4939 participants. This study was approved as exempt by the Washington University in St Louis Institutional Review Board (IRB#: 202201153).

Exploratory factor analysis (EFA) reduces a large set of items to a smaller number of factors, each composed of multiple items. We used a scree plot to identify the number of factors to extract and weighted least squares to estimate parameters for the EFA. Because the factors were likely correlated with each other, we used the promax oblique rotation [10]. We evaluated the results using global fit indices. Following Brown [11], we examined χ^2 and standardized root mean square residual (SRMR) as absolute fit indices, root mean square error of approximation (RMSEA) [12] as a parsimony correction fit, and comparative fit indices (CFI) [13] as a form of comparative fit. A good fit would include a non-significant χ^2, SRMR ≤ 0.8, CFI ≥ 0.95, and RMSEA $< .06$. A CFI ≥ 0.90 and ≤ 0.95 along with RMSEA < 0.08 indicate acceptable fit [13].

Often, EFA is followed by restricted or confirmatory factor analysis (CFA); however, CFA has many restrictive assumptions that may not be realistic [15,16]. For example, CFA requires that all cross-loadings are exactly zero, which is an assumption that is unlikely to be met in applied datasets, particularly in a measure such as the AGPM, which examines two domains of variables at once (attitudes toward specific activities and cross-cutting benefits and concerns) [16]. As an alternative to CFA, EFA can be followed by unrestricted factor analysis (UFA) [16]. UFA can be used to specify the number of factors *a priori* and substantive indicators for each factor while allowing for small (aimed to be close to zero as much as possible) cross-loadings. A UFA allows the researcher to incorporate an approximate *a priori* knowledge about the pattern of factor loadings (based on the EFA results) but not have to resort to restrictive assumptions when estimating measurement model parameters.

To use the EFA followed by UFA strategy, we first divided our full sample into two groups at random (group 1, $n = 2460$ and group 2, $n = 2479$). We used descriptive statistics, *t*-tests, and chi-squared tests to compare demographic characteristics of participants across the two groups to ensure there were no notable differences that might impact the factor analyses (Table 1). Demographics compared were selected based on prior research that found age, gender, race, education, employment status, income, and political affiliation to have a significant association with one or more of the original AGPM factors [5]. After comparing the two groups to ensure they were roughly equivalent, we conducted EFA of the AGPM.v23 in order to identify the underlying factors.

Following EFA with group 1, a UFA was conducted with group 2 using weighted least squares as the estimator and a Procrustes rotation [17], which allows for a targeted factor rotation based on the pattern of factor loadings from the group 1 EFA. We compared the group 1 EFA with the rotated group 2 results using Tucker's congruence coefficient to determine the similarity between the factors from the two groups [18].

Once the factor structure was confirmed, we compared the updated factors with the original factors [5]. Given our large sample size, we set alpha to 0.01, so inferential results with a *p*-value less than 0.01 were considered statistically significant.

We used R version 4.3.0 and RStudio version 2023.06.2 build 561 to conduct analyses. R packages used included foreign, psych, here, tidyverse, EFA.dimensions, flextable, sjPlot, and knitr.

Results

We found no significant differences between the two groups for race, employment, gender, ethnicity, household income, political party, education, or age (Table 1). We did not include the overall general support items in the factor analyses since they were not written to represent latent factors but computed a Cronbach's alpha for the six general support items as a measure of reliability (Cronbach's $\alpha = 0.82$). The distribution of results for all participants for the items included in the factor analyses is shown in Fig. 1 and grouped by factor.

The EFA of group 1 data ($n = 2460$) identified seven factors; the items and item factor loadings are shown in Table 2. All primary factor loadings had a magnitude of 0.37 or higher; while all items loaded most heavily on their primary factor, six of the items cross-loaded at ≥ 0.3 magnitude on a second factor. The overall R^2 of 0.66 indicated the model explained 66% of the total variance in the data. The seven final factors and their variance explained (R^2) and Cronbach's α were health benefits ($R^2 = 0.94$, $\alpha = 0.89$), sacredness of life concerns ($R^2 = 0.92$, $\alpha = 0.82$), privacy concerns ($R^2 = 0.93$, $\alpha = 0.88$), knowledge benefits ($R^2 = 0.9$, $\alpha = 0.79$), gene editing concerns ($R^2 = 0.91$, $\alpha = 0.83$), mRNA vaccine concerns ($R^2 = 0.95$, $\alpha = 0.87$), and social justice concerns ($R^2 = 0.86$, $\alpha = 0.81$), indicating that the model was a good fit for the observed data. Cronbach's αmeasures internal validity or how strongly the items in the factor correlate with each other; values above 0.7 are considered acceptable. The factor R^2 estimates the percentage of variance in the latent factors that the estimated factors would explain [18]. The model χ^2 was 1334.59 with a *p*-value less than

https://doi.org/10.1017/cts.2025.38 Published online by Cambridge University Press

Table 1. Comparison of two groups of participants who completed a survey on values and attitudes toward genomics and genomic healthcare (total $n = 4939$; survey year = 2023)

Characteristic	Category	Total	Group 1 $n = 2460$ n (%)	Group 2 $n = 2479$ n (%)	p
Race category	American Indian or Alaska native	23 (0.5)	12 (0.5)	11 (0.4)	0.189
	Asian	243 (4.9)	123 (5.0)	120 (4.8)	
	Black or African American	837 (16.9)	409 (16.6)	428 (17.3)	
	Native Hawaiian/Other Pac Islander	12 (0.2)	10 (0.4)	2 (0.1)	
	Two or more races	152 (3.1)	68 (2.8)	84 (3.4)	
	White	3672 (74.3)	1838 (74.7)	1834 (74.0)	
Employment	Caregiver or homemaker	195 (3.9)	98 (4.0)	97 (3.9)	0.997
	Employed full-time	2086 (42.2)	1031 (41.9)	1055 (42.6)	
	Employed part-time	683 (13.8)	346 (14.1)	337 (13.6)	
	Other employment type	160 (3.2)	79 (3.2)	81 (3.3)	
	Retired	870 (17.6)	439 (17.8)	431 (17.4)	
	Self-employed	487 (9.9)	241 (9.8)	246 (9.9)	
	Unemployed	458 (9.3)	226 (9.2)	232 (9.4)	
Gender	Male	2403 (48.7)	1235 (50.2)	1168 (47.1)	0.070
	Female	2487 (50.4)	1204 (48.9)	1283 (51.8)	
	More options please	49 (1.0)	21 (0.9)	28 (1.1)	
Ethnicity	Hispanic or Latino	289 (5.9)	149 (6.1)	140 (5.6)	0.140
	Not Hispanic or Latino	4589 (92.9)	2288 (93.0)	2301 (92.8)	
	Prefer not to answer ethnicity	61 (1.2)	23 (0.9)	38 (1.5)	
Education	Less than high school	42 (0.9)	24 (1.0)	18 (0.7)	0.323
	High school	662 (13.4)	329 (13.4)	333 (13.4)	
	Some college	1053 (21.3)	531 (21.6)	522 (21.1)	
	Associate's degree	525 (10.6)	245 (10.0)	280 (11.3)	
	Bachelor's degree	1696 (34.3)	860 (35.0)	836 (33.7)	
	Master's degree (e.g., MPH, MA, MS)	730 (14.8)	353 (14.3)	377 (15.2)	
	Doctoral degree (e.g., PhD, ScD, DNP, MD, PsyD, EdD)	202 (4.1)	108 (4.4)	94 (3.8)	
	Other education level	29 (0.6)	10 (0.4)	19 (0.8)	
Political party	Republican	1126 (22.8)	563 (22.9)	563 (22.7)	0.596
	Democrat	2456 (49.7)	1207 (49.1)	1249 (50.4)	
	Independent	1357 (27.5)	690 (28.0)	667 (26.9)	
Household income	$0–25,000	756 (15.3)	395 (16.1)	361 (14.6)	0.194
	$25,001–50,000	1182 (23.9)	587 (23.9)	595 (24.0)	
	$50,001–75,000	972 (19.7)	454 (18.5)	518 (20.9)	
	$75,001–100,000	692 (14.0)	337 (13.7)	355 (14.3)	
	$100,001–150,000	759 (15.4)	392 (15.9)	367 (14.8)	
	Greater than $150,000	475 (9.6)	237 (9.6)	238 (9.6)	
	Prefer not to answer Income	103 (2.1)	58 (2.4)	45 (1.8)	
Age	Mean (SD)	46.4 (17.0)	46.6 (16.9)	46.2 (17.1)	0.393

0.001, indicating a significant difference between expected and observed values in the correlation matrix and suggesting some lack of fit. Although χ^2 is widely reported in applied studies, it is rarely utilized as the sole index of overall fit because of its tendency to reject large-N solutions even when differences are negligible. On the other hand, both RMSEA (0.068; 90% CI: 0.067–0.071) and CFI (0.93) suggested acceptable fit, and SRMR (0.02) indicated good fit.

https://doi.org/10.1017/cts.2025.38 Published online by Cambridge University Press

Figure 1. Distribution of 4939 participant responses to the attitudes toward genomics and precision medicine items in a survey on values and attitudes toward genomics and genomic healthcare (2023) grouped by factor.

https://doi.org/10.1017/cts.2025.38 Published online by Cambridge University Press

Table 2. Exploratory factor analysis loadings for responses from 2460 survey participants who completed a survey on values and attitudes toward genomics and genomic healthcare (2023)

Characteristic	Health benefits	Sacredness of life concerns	Privacy concerns	Gene editing concerns	Knowledge benefits	mRNA vaccine concerns	Social justice concerns	Original AGPM factor
Prenatal genetic testing is useful because it can help parents to prepare for different possibilities	0.84							Perceived Benefit
[b]Prenatal genetic testing could help reduce parents' worry about the health of their baby	0.76							Embryo Concerns
[b]Prenatal genetic testing is a good thing because it helps parents have healthy children	0.71	(-0.33)						Embryo Concerns
[b]Gene editing seems exciting because it could fix certain diseases	0.74			(-0.49)				Nature Concerns
[b]Stem cell research with embryos is valuable because it advances medical knowledge	0.48	(-0.41)						Embryo Concerns
[b]Eliminating genetic diseases for future generations is a good idea	0.68			(-0.39)				Nature Concerns
[b]I support funding both kinds of stem cell research to cure diseases	0.45	(-0.36)						Embryo Concerns
Storing tissue and genetic information is important because it could improve people's health	0.47		(-0.42)					Perceived Benefit
I am concerned that prenatal genetic testing during pregnancy will lead to abortions		0.87						Embryo Concerns
It is unacceptable to have an abortion because of a genetic condition		0.80						Embryo Concerns
It bothers me that embryonic stem cell research destroys embryos		0.76						Embryo Concerns
The idea of growing organs disturbs me		0.46						Embryo Concerns
Prenatal genetic testing suggests that people who are living with genetic diseases have less value		0.37						Embryo Concerns
I worry about what researchers would do with my samples if they are stored			0.87					Privacy Concerns
I would be concerned if many different researchers had access to my data			0.87					Privacy Concerns
I have concerns about how my information will be kept private			0.83					Privacy Concerns
I worry that health and lifestyle information that is stored electronically could be hacked			0.72					Privacy Concerns
[a,b]I am happy to share my health and lifestyle information with researchers	(-0.35)		0.64					Privacy Concerns
I would make better health choices if I knew I was at higher risk of getting a disease					0.86			Perceived Benefit
It would be a relief to know what diseases I am at higher risk of getting in the future					0.82			Perceived Benefit
Genetic testing would help me make decisions about my health					0.81			Perceived Benefit
I am curious to know about my own genes					0.68			Perceived Benefit
[b]It is not always better to know more about the future					−0.37			Perceived Benefit
Gene editing sounds alarming				0.81				Nature Concerns

(*Continued*)

https://doi.org/10.1017/cts.2025.38 Published online by Cambridge University Press

Table 2. (*Continued*)

Characteristic	Health benefits	Sacredness of life concerns	Privacy concerns	Gene editing concerns	Knowledge benefits	mRNA vaccine concerns	Social justice concerns	Original AGPM factor
I am concerned about making any changes to genes that will be passed on to future generations				0.75				Nature Concerns
I am concerned that people will undergo gene editing before potential side effects are known				0.64				Nature Concerns
I think gene editing is wrong because it is like playing God		(0.30)		0.51				Nature Concerns
I worry that gene editing will be used to change traits that are not health related like eye color				0.51				Nature Concerns
[a]mRNA vaccines could protect my health						0.89		New Item
[a]mRNA vaccines could protect the health of the most vulnerable people in society	(-0.33)					0.86		New Item
I am concerned that mRNA vaccines might change human bodies in ways that are unknown						0.79		New Item
I worry that people will be required to get mRNA vaccines						0.77		New Item
Genetic testing could make it hard to get insurance							0.82	Social Justice Concerns
Employers might use the results of genetic testing to hire only certain people							0.81	Social Justice Concerns
Genetic tests could cause people to be treated unfairly							0.77	Social Justice Concerns

Note: Cross-loadings (≤.3) on latent factors other than the primary factor are denoted by parentheses.
[a]Item was reverse scored in the revised measure.
[b]Item was reverse scored in the original measure.

Following EFA with group 1, we conducted a UFA with group 2 using Procrustes rotation [19]. Tucker's congruence coefficient was 0.99, indicating that the factors from the two groups were essentially equivalent. The model χ^2 was 1545.84 with a p-value less than .001. The SRMR of 0.02 indicated a good fit. The root mean square error of approximation (RMSEA) was 0.073 (90% CI: 0.071–0.075), and the CFI was 0.93, both suggesting a moderate fit.

The original AGPM factor structure contained five factors: embryo concerns, privacy concerns, perceived benefits, nature concerns, and social justice concerns. The original factor for each item is shown in the last column in Table 2. With the exception of the health benefits factor, items loaded together in a way consistent with the prior factor structure. Eight items were reverse scored in the original AGPM (i.e., a response of strongly agree was originally coded as 7 but reverse coded as 1, and strongly disagree was originally coded as 1 and reversed coded to be 7 with the other categories reversed to match the new order), with six loading on a concerns factor in the original AGPM that now load on the new health benefits factor in the updated AGPM. The other two items originally reverse scored also show consistency between the original AGPM and the updated AGPM. The new mRNA items all loaded together on a single factor. Two of the mRNA items were reverse scored to be consistent with the other mRNA items where agreement with the statement suggests concern about the mRNA vaccine.

Limitations

The AGPM.v23 was validated within a US context in 2023. Responses to the AGPM.v23 may have been affected by societal events and cultural factors. The length of the AGPM completion (estimated at 15 minutes) could present a barrier for some studies. As a global measure of GPM attitudes, the AGPM will need to be updated as technologies evolve.

Discussion

This brief report examined updates to the pre-pandemic AGPM items and factor structure [5] after introducing new items about mRNA vaccines. In the final factor structure, all of the mRNA items loaded together onto one factor. We thought the mRNA items might load on other factors like social justice, health benefits, or privacy. However, given the politicized environment at the time of the survey, and the wide-ranging vaccine hesitancy reasons many of which were not related to genomic medicine (e.g., the perception of rushed development or the belief that the vaccines contain microchips to track people), it is not surprising the mRNA items grouped together into a single factor. It is possible that the mRNA items may load on other factors (e.g., health benefits) in similar ways to other GPM activities when COVID-19 vaccine development is further in the past.

https://doi.org/10.1017/cts.2025.38 Published online by Cambridge University Press

GPM activities play an important role in promoting and protecting public health, as in the case of the COVID-19 vaccine, which was demonstrated effective at reducing the risk of severe disease and death [20]. However, vaccine uptake was lower among people with higher levels of religion, putting religious people at higher risk for more severe disease and death [3]. The AGPM.v23 instrument provides one option for building a better understanding role of religion in public attitudes toward GPM. In future papers and studies, we will present findings using the AGPM.v23 that help illuminate why religion and other demographic factors are associated with greater concerns about mRNA and other GPM activities, pointing to new opportunities for engagement with communities to achieve greater mutual understanding and identify potential paths for addressing concerns.

Author contributions. JKH conducted the analyses and wrote several sections of the paper; JMD led the project and wrote several sections of the paper; EDS reviewed and edited multiple drafts and wrote sections of the paper; KB led data collection and reviewed drafts of the paper; LB reviewed the data collection instruments and drafts of the paper; and EGC conducted the analyses, wrote sections of the paper, and reviewed the final draft of the paper.

Funding statement. Funded by the NHGRI award number: 5R01HG012830-02.

Competing interests. There are no known conflicts of interest.

References

1. **Hudson K, Lifton R, Patrick-Lake B, *et al.*** The precision medicine initiative cohort program - building a research foundation for 21st century medicine, *Precision Medicine Initiative (PMI) Working Group Report to the Advisory Committee to the NIH Director*. September 17, 2015, Accessed on June 23, 2024, https://www.nih.gov/sites/default/files/research-training/initiatives/pmi/pmi-working-group-report-20150917-2.pdf
2. **Piccaluga PP, Di Guardo A, Lagni A, *et al.*** COVID-19 vaccine: between myth and truth. *Nato Adv Sci Inst Se*. 2022;**10**(3):349. doi: 10.3390/vaccines10030349.
3. **Imran MH, Leng X, Iqbal M.** The role of religious belief in COVID-19 vaccine hesitancy. *Pastoral Psych*. 2024;**1**(5):609–629. doi: 10.1007/s11089-024-01147-6.
4. **Dolan DD, Lee SSJ, Cho MK.** Three decades of ethical, legal, and social implications research: looking back to chart a path forward. *Cell Genomics*. 2022;**2**(7):100150. doi: 10.1016/j.xgen.2022.100150.
5. **DuBois JM, Mozersky J, Antes A, English T, Parsons MV, Baldwin K.** Attitudes toward genomics and precision medicine. *J Clin Transl Sci*. 2021;**5**(1):e120. doi: 10.1017/cts.2021.774.
6. **Jones JM.** In U.S., 47% identify as religious, 33% as spiritual. September 22, 2023. Accessed on June 23, 2024, https://news.gallup.com/poll/511133/identify-religious-spiritual.aspx.
7. **Nortey J, Lipka M, Alvarado J.** Few Americans blame God or say faith has been shaken amid pandemic, other tragedies. November 23, 2021. Accessed on June 23, 2024, https://www.pewresearch.org/religion/2021/11/23/few-americans-blame-god-or-say-faith-has-been-shaken-amid-pandemic-other-tragedies/.
8. **Alper BA, Rotolo M, Tevington P, Nortey J, Kallo A.** Spirituality among Americans. December 7, 2023. Accessed on June 23, 2024, https://www.pewresearch.org/religion/2023/12/07/spirituality-among-americans/.
9. **Fahmy D.** Highly religious Americans more skeptical of human enhancements such as brain implants, gene editing. May 4, 2022. Accessed on June 23, 2024, https://www.pewresearch.org/short-reads/2022/05/04/highly-religious-americans-more-skeptical-of-human-enhancements-such-as-brain-implants-gene-editing/.
10. **Yong AG, Pearce S.** A beginner's guide to factor analysis: focusing on exploratory factor analysis. *Tutorials in Quantitative Methods for Psychology*. 2013;**9**(2):79–94. doi: 10.20982/tqmp.09.2.p079.
11. **Brown TA.** *Confirmatory Factor Analysis for Applied Research*. New York, NY: The Guilford Press, 2015.
12. **Steiger JH.** Statistically based tests for the number of common factors. In: *Annual Meeting of the Psychometric Society*, Iowa City, 1980.
13. **Bentler PM.** Comparative fit indexes in structural models. *Psychol Bull*. 1990;**107**(2):238–246.
14. **Hu L, Bentler PM.** Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*. 1999;**6**(1):1–55.
15. **Lorenzo-Seva U, Ferrando PJ.** IMINCE: an unrestricted factor-analysis-based program for assessing measurement invariance. *Behavior Research Methods, Instruments, & Computers*. 2003;**35**(2):318–321. doi: 10.3758/bf03202558.
16. **Steenkamp JB, Maydeu-Olivares A.** Unrestricted factor analysis: a powerful alternative to confirmatory factor analysis. *J Acad Market Sci*. 2022;**51**(1):86–113. doi: 10.1007/s11747-022-00888-1.
17. **McCrae RR, Zonderman AB, Costa PT, Bond MH, Paunonen SV.** Evaluating replicability of factors in the revised NEO personality inventory: confirmatory factor analysis versus Procrustes rotation. *J Pers Soc Psychol*. 1996;**70**(3):552–566. doi: 10.1037/0022-3514.70.3.552.
18. **Grice JW.** Computing and evaluating factor scores. *Psychol Methods*. 2001;**6**(4):430–450. doi: 10.1037/1082-989X.6.4.430
19. **Lorenzo-Seva U, ten Berge JMF.** Tucker's congruence coefficient as a meaningful index of factor similarity. *Methodology*. 2006;**2**(2):57–64. doi: 10.1027/1614-2241.2.2.57.
20. **Beladiya J, Kumar A, Vasava Y, *et al.*** Safety and efficacy of COVID-19 vaccines: a systematic review and meta-analysis of controlled and randomized clinical trials. *Rev Med Virol*. 2023;**34**(1):989. doi: 10.1002/rmv.2507.