**Examining the Validity of the Drivers of COVID-19 Vaccination Acceptance Scale using Rasch Analysis**

Chia-Wei Fan[1†], Jung-Sheng Chen[2†], Frimpong-Manso Addo[3], Emma Sethina Adjaottor [3], Gifty Boakye Amankwaah[3], Cheng-Fang Yen[4,5,6†], Daniel Kwasi Ahorsu[7]*, Chung-Ying Lin[8,9,10]*

[1]Department of Occupational Therapy, AdventHealth University, Orlando, Florida, USA.
[2]Department of Medical Research, E-Da Hospital, Kaohsiung 82445, Taiwan
[3]Department of Behavioural Sciences, Kwame Nkrumah University of Science and Technology, Ghana
[4]Department of Psychiatry, School of Medicine College of Medicine, Kaohsiung Medical University, Kaohsiung 80708, Taiwan
[5]Department of Psychiatry, Kaohsiung Medical University Hospital, Kaohsiung 80756, Taiwan
[6]College of Professional Studies, National Pingtung University of Science and Technology, Pingtung 91201, Taiwan
[7]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
[8]Institute of Allied Health Sciences, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[9]Department of Occupational Therapy, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[10]Department of Public Health, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[†] These authors contributed equally to the study.
**Co-Correspondence:** C.-Y. Lin, PhD, Institute of Allied Health Sciences, College of Medicine, National Cheng Kung University, 1 University Road, East District, Tainan 701, Taiwan. **E-mail:** cylin36933@gmail.com; cy.lin@polyu.edu.hk; **Tel:** 852-2766-6755; **Fax:** 852-2330-8656
**Co-Correspondence:** Daniel Kwasi Ahorsu, PhD, D Department of Rehabilitation Sciences, Faculty of Health and Social Sciences, The Hong Kong Polytechnic University, 11 Yuk Choi Rd, Hung Hom, Hong Kong. **E-mail:** daniel.ahorsu@connect.polyu.hk

**Declaration of Interests**
All the authors declare that there is no conflict of interest. The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

**Author contributions**
C-W Fan, J-S Chen, ES Adjaottor, F-M Addo, GB Amankwaah, DK Ahorsu, C-F Yen, and C-Y Lin contributed to the conception and design of the study; J-S Chen, ES Adjaottor, F-M Addo, GB Amankwaah, and DK Ahorsu organized the database; C-W Fan performed the statistical analysis; C-W Fan, J-S Chen, C-F Yhn, DK Ahorsu, and C-Y Lin interpreted the

**Abstract**

**Background:** To well control the pandemic of COVID-19, herd immunity should be achieved. However, people, especially those with better physical conditions (e.g., young adults), may not accept COVID-19 vaccines. Understanding university students' willingness or reluctance to uptake COVID-19 vaccination is important.

**Aim:** This study aimed to examine the psychometric properties of the DrVac-COVID19S, an instrument that helps assess motivations/drivers of COVID-19 vaccination uptake among university students.

**Research design and methods:** Using convenience sampling and cross-sectional design, university students (930 from Taiwan [38.0% males] and 1,244 from Ghana [63.3% males]) completed the DrVac-COVID19S using an online survey (Taiwanese students) or paper-and-pen method (Ghanaian students). Rasch analysis was used to examine the psychometric properties of the DrVac-COVID19S.

**Results:** All 12 items in the DrVac-COVID19S had a satisfactory fit in the Rasch models (infit MnSq=0.74 to 1.49; outfit MnSq=0.72 to 1.42). Moreover, the seven-point Likert scale used in the DrVac-COVID19S demonstrated monotonically increasing in their difficulties, which indicated the ordered category. Additionally, no differential item functioning was displayed in the DrVacCOVID-19S across Taiwanese and Ghanaian students.

**Conclusions:** The DrVacCOVID-19S has good psychometric features to help healthcare providers assess individuals' (especially university students) motivations or drivers to get the COVID-19 vaccination.

**Keywords:** COVID-19; Rasch; psychometric testing; vaccine hesitancy; vaccination uptake

**1.0. Introduction**

Acute pneumonia coronavirus disease 2019 (COVID-19) was first identified in late 2019 in China and has made a devastating impact worldwide [1-2]. The World Health Organization (WHO) declared COVID-19 a pandemic and later provided associated instructions and clinical management for its detection, treatment, prevention, and control strategies [3]. Additionally, clinical guidelines have been developed to maximize community protection and prevent possible spreading, such as wearing a mask, staying 6 feet from others, and getting vaccinated [4]. Vaccination has been considered one of the most reliable and cost-effective public health interventions over the years [5-6]. Based on early estimates of COVID-19's infectiousness, herd protection can be achieved if at least 70% of the population gets infected or gets a protective vaccine to be immune [7]. Hence, the uptake rate of COVID-19 vaccination is the key to preventing further outbreaks [8]. However, vaccine hesitancy continues to be a pressing problem and was listed as a top ten threat to the health of the global population [9]. Therefore, understanding individuals' underlying attitudes and considerations regarding COVID-19 vaccination is extremely important to promoting the uptake of the COVID-19 vaccine, especially for young adults, given they usually have good physical health and are likely to refuse vaccination uptake [10]. Furthermore, misinformation about the COVID-19 vaccine has been increasingly prevalent throughout the pandemic [11-13]. For example, some misinformation mentions that young adults, including university students, are less likely to contract COVID-19 and less likely to experience severe symptoms, possibly contributing to the university population's low vaccination rate [14].

The COVID-19 Vaccination Acceptance Scale (DrVac-COVID19S, also known as the Motors of COVID-19 Vaccination Acceptance Scale; MoVac-COVID19S) was developed by

adapting the Motors of Influenza Vaccination Acceptance Scale (MoVac-Flu Scale) [15] to assess individuals' attitudes and considerations concerning COVID-19 vaccination uptake [16]. The survey was used to measure constructs rather than particular items; therefore, it is important to know whether the items and the underlying structure within the DrVac-COVID19S largely influence test scores and research conclusions. The preliminary psychometric properties examination results supported satisfactory internal consistency, and item structure corresponded with the cognitive model of empowerment (CME); that is, four traits (value, impact, knowledge, and autonomy) are found in the DrVac-COVID19S [17]. In addition, it has excellent known-group validity [16]. More specifically, the enrolled participants with higher compliance to preventive COVID-19 behaviors had significantly higher DrVac-COVID19S scores than those with lower compliance to preventive behaviors [16]. Further, the measurement invariance across countries (Taiwan vs. China), gender (male vs. female), and participants' college majors (health-related vs. non-health-related) has established that the different subgroups interpreted items similarly [18]. In order words, the items of the DrVac-COVID19S were found to be equivalent across three different subgroups. The confirmatory factor analysis results also showed that DrVac-COVID19S has a four-factor structure (i.e., values, impacts, knowledge, and autonomy) identifying individuals' vaccination acceptance [18].

Although strong psychometric properties of the DrVac-COVID19S have been established [16, 18], an extensive evaluation of the psychometric properties with the modern test theory, Rasch analysis, has never been examined. The Rasch model is a probabilistic model, which estimates the participants' characteristics and the item difficulty [19]. It has been extensively used in assessment development in health-related research, as it enlightens a mechanism to optimize test items [20].

There are two fundamental assumptions when applying the Rasch model. First, a person with more ability would always have a higher possibility of passing any test items than someone with less ability. Second, a test item considered harder would be perceived harder by any person than a test item that is considered easier. Based on these assumptions, the Rasch model linearly transforms the raw scores into interval measures, and the enrolled subjects and test items can be scaled along a single linear latent continuum so that the person's characteristics (in this case, participants' attitude and consideration for COVID-19 vaccination) and item difficulty can be compared. As a result, Rasch analysis is increasingly recognized as a more powerful examination of item and scale performance, which can inform clinical decision-making [21]. Moreover, the Rasch model features a sample-free model [22] because the outcome of the Rasch analysis is governed only by the person's ability and the item's difficulty. In this regard, even though the current study only examined the DrVac-COVID19S on university students, the findings can be generalized to nonstudents due to the sample-free principle.

Therefore, the current study aimed to examine the psychometric properties of the DrVac-COVID19S scale further using Rasch analysis on university students in two regions (i.e., Taiwan and Ghana). Specific aims of the study were to (1) examine the scale structure and functioning based on the four latent traits (i.e., Values, Impacts, Knowledge, and Autonomy); (2) examine the unidimensionality to confirm construct validity; (3) examine person response validity to ensure subjects targeting; (4) examine the differentiate item function to detect evaluation bias across subpopulations; and (5) access the criterion-related validity.

## 2.0. Methods

### 2.1. Participants and Study Procedures

Taiwanese and Ghanaian students were the target participants in the present study because the Taiwanese authorities rapidly introduced a range of policies to effectively control the spread of COVID-19 in the early pandemic stage [13]; similarly, Ghana activated several activities in the early stage of the pandemic to help reduce the spread of COVID-19 [23-24]. Therefore, it is important for Taiwanese and Ghanaian citizens to increase their willingness to take COVID-19 vaccination to avoid further serious COVID-19 outbreaks.

The study participants were students from the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana and several universities in Taiwan. At KNUST, permission was sought from department heads and respective lecturers whose class was used for the data collection. The prospective participants were informed about the purpose of the study and their rights and ethical considerations (to withdraw anytime time without any consequence, confidentiality, anonymity, etc.) involved with responding to the questionnaires. Specifically, the lecturers disseminated the survey information to the students before the end of a class. Those interested in this study used some time to complete the survey using the paper-and-pencil method. Hence, only participants who were available and willing to participate in the study responded to the questionnaire. Moreover, given that English is Ghana's official language, the Ghanaian participants completed the English survey (see Appendix A for detailed item contents). This procedure was repeatedly used to collect 1,244 (out of 1,500) questionnaires across several departments and schools in the university between January 25 to March 12, 2021.

In Taiwan, data were collected from university students using Google Forms. Information about the study was promulgated by departments and faculties of several Taiwan universities. When a participant begins the Google Forms, detailed information regarding the study purpose and the participant's rights is clearly described on the first page. The online survey questions are

only readable after the participant hits the agree icon to express their willingness to participate.

The data were collected between January 5 and February 5, 2021, with 924 out of 932 questionnaires collected. Eight were excluded due to inadequate responses but were used for the analysis. Moreover, given that traditional Chinese is Taiwan's official language, the Taiwanese participants completed the traditional Chinese survey (see Appendix A for detailed item contents). The English DrVac-COVID19S was translated into traditional Chinese using the standard translation procedure, including forward translation, back translation, and pretests.

Informed consent (paper and e-copy for Ghanaians and Taiwanese, respectively) was signed before the data collection. This study was approved by the Institutional Review Board (IRB) of the Kaohsiung Medical University Chung-Ho Memorial Hospital (IRB ref: KMUHIRB-EXEMPT(I)-20200119) and Kwame Nkrumah University of Science and Technology (IRB ref: CHRPE/AP/283/21).

## 2.2.  Measurement

### 2.21.  DrVac-COVID19S

The DrVac-COVID19S has a solid theoretical background as it was adapted from the well-developed MoVac-Flu Scale [15], which is based on the Cognitive Model of Empowerment (CME) [17]. The main contents of the DrVac-COVID19S and the MoVac-Flu Scale remained the same. The only change made was switching the word "flu" to "COVID-19" in test items. DrVac-COVID19S consists of 12 items and are rated with a 7-point Likert scale. These 12 items correspond to the CME model: Values (Items 3, 6, and 8), Impacts (Items 1, 4, and 12), Knowledge (Items 2, 5, and 10), and Autonomy (Items 7, 9, and 11). Items in each domain were

added up as a domain sum score. A higher score indicates a higher acceptance of the COVID-19 vaccine.

The CME assumed that empowerment should be viewed as an innate drive that urges people to engage in purposeful behaviors. Additionally, these drives arise from four distinct cognitive processes: Values, Impacts, Knowledge, and Autonomy. In the specific case of DrVac-COVID19S, these four components should be considered: (1) University students' consideration of the purposes of the vaccine uptake and their feeling of the value of this behavior; (2) University students' belief that the COVID-19 vaccine uptake behavior would make a difference to achieve its purpose (i.e., avoid infection transmission, decrease serious symptoms, etc.); (3) University students' comprehension of information and knowledge about the COVID-19 vaccine uptake, or the belief that they have sufficient knowledge regarding COVID-19 vaccine uptake; and (4) University students' feelings of free choice to uptake the COVID-19 vaccine or the belief that the initiation of the COVID-19 uptake behavior is self-determined.

2.22. Other assessment

Two questions were used to investigate the participants' willingness to uptake the COVID-19 vaccine. The first question, "When a COVID-19 vaccine becomes available, will you get vaccinated?" was rated with a 4-point Likert-type scale, with 1= Definitely not willing, 2= Not sure, 3= If my doctor recommends it for me, I will get it, and 4= Definitely willing. The score for the second question, "Please rate the current level of your willingness to receive a COVID-19 vaccine," ranged from 1-10, with 1 = very low and 10 = very high.

2.23 Demographic survey

The demographic survey asked participants to provide their gender, age, educational level, and marital status.

## 2.3. Data Analysis

Rasch analyses were used to examine the DrVac-COVID19S' functioning, test unidimensionality, assess person-response validity, and differentiate item function (DIF) across subgroups (i.e., country and gender). Previous studies have identified that the four-trait-factor model outperformed the one-trait-factor model [16, 18]; thus, the four domains were examined separately in Rasch analysis in the current study.

In the scale functioning, the 7-point Likert scale was examined to ensure sufficient subjects (i.e., over 10) participated in each rating category. Also, we examined if the average calibrations for each rating level advanced monotonically. Last, we examined the outfit mean squares (MnSq) as it is more sensitive to unexpected observations/outliers, and it should be less than 2.

Second, the test unidimensionality of the DrVac-COVID19S was examined with the goodness-of-fit statistics for the four-factor structures (i.e., values, impacts, knowledge, and autonomy). According to the Rasch measurement model's expectations, the fit analysis examines how well the data align with those additive measures. The infit MnSq should be 0.5 to 1.5 with a standardized mean square score (Zstd) between -2 to +2 [25]. If mean square statistics are acceptable, the Zstd can be ignored because mean squares near 1 indicate little distortion of the scoring system, regardless of the Zstd value. However, if an infit MnSq >1.5 suggests a deviation from unidimensionality, it should be concerned with the scale [19]. Rasch analysis can also be used to investigate the hierarchy of items in DrVac-COVID19S.

Additionally, we examined the person-response validity to see how well the enrolled subjects fit the model's expectation. The criteria were set as the infit and outfit MnSq between

0.5 to 1.5 associated with a Zstd between -2 to +2. We expected that 95% of the enrolled subjects would have acceptable infit statistics to confirm the person-response validity [26], which indicated that the DrVac-COVID19S was used in subjects with an appropriate range of individuals' attitudes and considerations in getting the COVID-19 vaccination. Also, the ceiling and floor effects were examined to see if any extreme values may detract from the reliability of the DrVac-COVID19S. If more than 15% of the total students achieved the maximum or minimum possible scores, this result was considered a ceiling effect and floor effect, respectively [27].

Further, we adopted the Differentiate Item Function (DIF) analysis to detect the potential interaction between subgroups (i.e., country and gender), which may cause underlying bias in test items [19]. DIF was checked if subjects from different countries (i.e., Taiwan vs. Ghana) or with different gender (i.e., male vs. female) possessed the same latent vaccination attitude and considerations but did not have the same probability of endorsing the DrVac-COVID19S test items. A significant interaction between variables would suggest that the test item was measuring an additional construct in one of the groups that might not be relevant to the intended construct of the measurement. It is generally accepted to have no more than one item in a scale, or 5% of the total items, which would demonstrate DIF to support unidimensionality [19, 28]. As DrVac-COVID19S is a relatively short questionnaire with only 12 items, we expected that there would be no DIF on any of the 12 items across the subgroups. DIF contrasts less than 0.5 logit is considered negligible; contrasts between 0.5 to 1 logit can be considered moderate; and contrasts over 1 as substantial, indicating that the DIF contrasts are statistically significant [26].

Last, we also examined the concurrent validity for the DrVac-COVID19S with the two vaccination willingness questions. Spearman correlation coefficient was used due to the nature of

the ordinal scales. The criteria were set at 0.1 to 0.3 = weak correlation; 0.4 to 0.7= moderate

correlation; > 0.7= strong correlation [29-30].

Facets Version 3.83.6 was used to perform the Rasch analysis. SPSS version 27 was used

to produce demographic-descriptive statistics and examine criterion-related validity.

## 3.0.  Results

The participants included 930 Taiwanese university students [mean age (SD) = 25.39

(6.46); 353 (38.0%) males] and 1,244 Ghanaian university students [mean age (SD) = 20.33

(1.74); 787 (63.3%) males]. The majority of them were single (82.2% Taiwanese and 90.6%

Ghanaian). Table 1 presents the participants' demographic details. Further, except for item two (I

know very well how vaccination protects me from the COVID-19), Taiwanese students had

higher average scores for all other DrVac-COVID19S items than Ghanaian students. Nine out of

12 (75%) DrVacCOVID-19S item scores significantly differed between Taiwanese and

Ghanaian datasets.

[Insert Table 1 here]

The Rasch results showed that DrVacCOVID-19S had sufficient subjects (i.e., over 10)

for each rating category for all items, which allowed precise estimation of step calibration in its

adjacent categories. Also, all items had average measures advance monotonically with the seven-

level Likert scale. Besides, all the test items had outfit MnSq less than the cut-off criteria of 2.

Detailed average measures across rating categories are presented in Table 2.

Additionally, the results showed that all the corresponding items in the respective

domains fitted well to the Rasch expectation with acceptable values of MnSq and Zstd (Table 2).

These findings confirmed the unidimensionality and supported the construct validity of the

DrVacCOVID-19S. The most difficult items in each domain were: *"It is important that I get the COVID-19 jab"* (Values), *"Getting the COVID-19 jab has a positive influence on my health"* (Impacts), *"How the COVID-19 jab works to protect my health is a mystery to me"* (Knowledge, reversed), and *"I get the COVID-19 jab only because I am required to do so"* (Autonomy, reversed). The measure logits ranged from -.40 to .26. Table 2 offers additional details.

The person-response validity analysis demonstrated that among the 2,174 participants, 2,052 (94.4%), 2,036 (93.7%), 2,013 (92.6%), and 2,038 (93.7%) had acceptable goodness-of-fit to the Rasch model in the Values, Impacts, Knowledge, and Autonomy domains, respectively, which were close to the criteria of 95%. Furthermore, when closely scrutinizing the actual pattern of rating for the DrVacCOVID-19S items, no ceiling effects (range 4.0% to 10.6%) or floor effects (range 0.9% to 2.5%) were found in the four subdomains. These results indicated that the DrVacCOVID-19S items were well targeted to the enrolled students' attitudes and considerations in getting the COVID-19 vaccination.

There was no significant DIF in any of the items within the DrVacCOVID-19S relative to either country or gender. The contrasts for each domain were -.11 to .18 (Values), -.27 to .23 (Impacts), -.33 to .26 (Knowledge), and -.17 to .14 (Autonomy) for the country variable (i.e., Taiwan vs. Ghana). In addition, the contrasts were -.15 to .09 (Values), -.08 to .14 (Impact), -.21 to .15 (Knowledge), and -.03 to .01 (Autonomy) for the gender variable (i.e., male vs. female).

[Insert Table 2 here]

The Spearman correlation between the DrVacCOVID-19S and the two vaccine willingness items indicated moderate correlation in Values (r = .476 to .517, p<0.001) and Impacts (r = .505 to .524, p<0.001) domains. In other words, individuals with higher Values or Impacts scores at the DrVacCOVID-19S would have a higher willingness to receive a COVID-

19 vaccine. Also, the Knowledge domain weakly correlates (r = .281 to .298) with vaccination willingness. There was no relationship between the Autonomy domain and individuals' vaccination willingness.

[Insert Table 3 here]

## 4.0. Discussion

Despite scientists' extensive efforts to achieve successful COVID-19 vaccines, a major obstruction has been observed towards the approved COVID-19 vaccination [31]. The low rate of COVID-19 vaccine acceptance has been considered a challenge [32-33]. Therefore, more studies are needed to address vaccine hesitancy, especially in the Middle East and North Africa, Sub-Saharan Africa, Eastern Europe, Central Asia, and Middle and South America [33]. Therefore, healthcare providers and policymakers need information that addresses the underlying considerations and hesitancy about the COVID-19 vaccination.

Furthermore, misinformation that young adults, including university students, are less likely to contract COVID-19 and less likely to experience severe symptoms has become increasingly prevalent throughout the pandemic, possibly attributing to the university population's low vaccination rate[14]. However, recent facts have shown that university students experienced protracted complications post-COVID [34] and are still at risk for long COVID [34-35].

Additionally, findings showed that university students' intention to uptake the COVID-19 vaccine was positively associated with the estimated social norms, so they feel accepted among peers [36]. Therefore, more efforts and actions should be taken to recognize and address factors possibly influencing university students' vaccination hesitation, which could have long-term

consequences on their health and education [37]. Creating and applying any survey must start with a theoretical foundation about the variables of interest, followed by rigorous procedures to evaluate how well the test items measure the chosen variables based on the theory [20]. The current study validated the psychometric properties of the DrVacCOVID-19S, which was developed according to the theoretical framework of CME. The Rasch results affirmed that the DrVacCOVID-19S has sound properties in its scale functioning, unidimensionality, item targeting, differentiate item functioning, and criterion validity. Thus, it provides a great tool to identify university students' concerns and the underlying obstacles preventing them from taking the vaccine. Furthermore, the four factors based on the CME allow healthcare providers, educators, or researchers to further develop associate programs to address the concerns identified by the DrVacCOVID-19S.

The Rasch analysis showed that all the items advanced monotonically in relation to the other items in the respective domains of DrVacCOVID-19S. Furthermore, all items demonstrated acceptable goodness-of-fit in the student population. The finding of unidimensionality of the four domains (i.e., Values, Impacts, Knowledge, and Autonomy) was consistent with previous study reports that there are four trait factors within the DrVacCOVID-19S [18].

The person response validity results showed no ceiling and flooring effects, which validated that the DrVacCOVID-19S items were well-targeted to the students' attitudes and consideration regarding the COVID-19 vaccine. However, the enrolled participants' goodness of fit was slightly less than the expected criteria of 95%. In other words, over 5% of students in this study were misfit participants who had unpredictable responses aligning with the difficulty of the items according to the Rasch model [38]. Although the goodness of fit statistics provided the

information needed to determine whether the participants idiosyncratically missed the easier items unexpectedly or passed the more difficult items accidentally, the underlying mechanism was unknown [39]. A previous study suggested that researchers place harsher expectations on the goodness of fit statistics to items rather than to enrolled participants [40], as the main focus of the assessment validation circles on the test items within a scale. Therefore, the current person response validity (92.6% - 94.4%) was slightly less than expected but still acceptable.

The result of no DIF relative to country and gender indicated that vaccination attitude and considerations might be regarded as similar across Taiwanese and Ghanaian students and male and female subgroups. In addition, the Rasch results were consistent with the measurement invariance analyses conducted with confirmatory factor analysis that regions (i.e., Taiwan vs. China), gender (male vs. female), and study majors (health-related vs. non-health related) did not exhibit significant variances across subgroups [18].

The analyses of the criterion validity of the DrVacCOVID-19S showed a weak to a moderate relationship with participants' willingness for vaccine uptake, which was consistent with Guidry et al.'s findings [41]. They explored the relationships between psychosocial predictors of willingness to get a COVID-19 vaccine. The results showed that if participants perceived the vaccine's positive value and understood its importance and impacts, they would be more willing to take a COVID-19 vaccine [41]. Therefore, the current study results further support the concurrent validity of the DrVacCOVID-19S.

With the psychometric findings supporting the use of the DrVacCOVID-19S, this may resolve the low vaccination rate in Taiwan (Taiwan expects to have a 60% coverage while only 30% had the first vaccine by the end of July) [42]. The DrVacCOVID-19S may thus help the Taiwan authorities to widen increases in the vaccination rates appreciably. Furthermore, the

DrVacCOVID-19S can help us understand the underlying reasons for unwillingness to uptake vaccines and devise appropriate programs to improve willingness.

Moreover, the misinformation about some vaccines (e.g., AstraZeneca's vaccine) may slow down the vaccination uptake rate in Africa [43-44] or make people hesitate to uptake vaccines. Therefore, the DrVacCOVID-19S may provide in-depth information to guide policymakers in determining whether they should improve their citizens' vaccine literacy.

## 4.1. Limitations and Recommendation for Future Study

The enrolled participants consisted of a convenience sample from university student populations. Hence, the generalization of the findings should be limited to the university student population as other populations might possess different traits of values, impact, knowledge, and autonomy toward the COVID-19 vaccine. Although the Rasch model posits the sample-free feature, this cannot guarantee that the psychometric findings from the Rasch model can be totally generalized to a population that has not been investigated. Therefore, future studies are still needed to explore the psychometric properties with other populations to increase the applicability of the DrVacCOVID-19S. Similarly, the generalizability issue should be cautious for the ethnic populations. Specifically, additional psychometric evidence for other countries is needed.

Also, the consistency of person response scoring patterns remains questionable in the current sample. We suggest future studies continue monitoring person response validity across different groups of participants to ensure that DrVacCOVID-19S is a viable way of assessing the concerns and attitudes surrounding the uptake of the COVID-19 vaccine in various students. Additionally, our study showed that certain university student sub-groups, such as medical students, students who uptake a flu vaccination in the previous year, and students with more concerns about the COVID-19 vaccine, would have higher vaccination intention [45]. However,

we did not collect the students' majors in the current study, so no DIF analysis can be performed to confirm whether there might be a potential item function difference among university students' majors. Future studies should consider student majors and further examine the assessment properties with this component.

Next, the study found that university students used multiple sources to learn about COVID-19 vaccines, including health agencies, mass media, and personal social networks [46]. Further studies can investigate how the different information sources might play a role in students' attitudes and concerns for the COVID-19 vaccine uptake.

Last, two administration forms (online survey vs. paper survey) were used in this study. Previous studies showed that online and paper-based surveys differ in response rate and cost [47]. Additionally, the paper survey was linked to enable participants to report higher health concerns and negative attitudes when the demographic characteristics were controlled [48]. Therefore, the different administration forms can potentially influence the results of the study. Future studies can consider using a single administration mode to reduce the potential bias.

## 4.2. Conclusion

The present study showed that the DrVacCOVID-19S had good psychometric features to help healthcare providers assess individuals' (especially university students) motivations or drivers to get the COVID-19 vaccination. Furthermore, given that the COVID-19 pandemic remains serious worldwide, governments and authorities should prioritize the achievement of herd immunity. Appropriate policies can be launched with tools like the DrVacCOVID-19S to deal with vaccine hesitancy among university students and help reach herd immunity globally.

**References**

[1] Helmy YA, Fawzy M, Elaswad A, Sobieh A, Kenney SP, Shehata AA. The COVID-19 pandemic: a comprehensive review of taxonomy, genetics, epidemiology, diagnosis, treatment, and control. J Clin Med. 2020;9(4):1225. doi: 10.3390/jcm9041225.

[2] Wu F, Zhao S, Yu B, Chen YM, Wang W, Song ZG, Hu Y, Tao ZW, Tian JH, Pei YY, Yuan ML, Zhang YL, Dai FH, Liu Y, Wang QM, Zheng JJ, Xu L, Holmes EC, Zhang YZ. A new coronavirus associated with human respiratory disease in China. Nature. 2020;579(7798):265-269. doi: 10.1038/s41586-020-2008-3.

[3] World Health Organization. (2021). WHO clinical management of severe acute respiratory infection when novel coronavirus (nCoV) infection is suspected. [Internet]. [updated 2021 January 25; cited 2021 July 14]; Available from:https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected.

[4] World Health Organization. (2021). How to protect yourself & others. [Internet]. [updated 2021 August 13; cited 2021 September 25]; Available from: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html

[5] Ehreth J. The value of vaccination: a global perspective. Vaccine. 2003;21(27-30):4105-4117. doi: 10.1016/s0264-410x(03)00377-3.

[6] Rodrigues C, Plotkin SA. Impact of vaccines; health, economic and social perspectives. Front Microbiol. 2020;11:1526. doi: 10.3389/fmicb.2020.01526

[7] D'Souza G, Dowdy D. What is herd immunity, and how can we achieve it with COVID-19? School of Public Health Expert Insights. [Internet]. [updated 2021 April 6; cited 2021 July

14]; Available from: https://www.jhsph.edu/covid-19/articles/achieving-herd-immunity-with-covid19.html

[8] El-Elimat T, AbuAlSamen MM, Almomani BA, Al-Sawalha NA, Alali FQ. Acceptance and attitudes toward COVID-19 vaccines: a cross-sectional study from Jordan. PLoS One. 2021;16(4):e0250555. doi: 10.1371/journal.pone.0250555.

[9] World Health Organization. (2019). Ten threats to global health in 2019. [Internet]. [cited 2021 July 14]; Available from:https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019

[10] Huang PC, Hung CH, Kuo YJ, Chen YP, Ahorsu DK, Yen CF, Lin CY, Griffiths MD, Pakpour AH. Expanding Protection Motivation Theory to explain willingness of COVID-19 vaccination uptake among Taiwanese university students. Vaccines. 2021;9:1046.

[11] Abena PM, Decloedt EH, Bottieau E, Suleman F, Adejumo P, Sam-Agudu NA, Muyembe TamFum JJ, Seydi M, Eholie SP, Mills EJ, Kallay O, Zumla A, Nachega JB. Chloroquine and Hydroxychloroquine for the prevention or treatment of COVID-19 in Africa: caution for inappropriate off-label use in healthcare settings. Am J Trop Med Hyg. 2020;102(6):1184-1188. doi: 10.4269/ajtmh.20-0290.

[12] Sefah IA, Ogunleye OO, Essah DO, Opanga SA, Butt N, Wamaitha A, Guantai AN, Chikowe I, Khuluza F, Kibuule D, Nambahu L, Abubakar AR, Sani IH, Saleem Z, Kalungia AC, Thi Phuong TN, Haque M, Islam S, Kumar S, Sneddon J, Wamboga J, Wale J, Miljković N, Kurdi A, Martin AP, Godman B. Rapid assessment of the potential paucity and price increases for suggested medicines and protection equipment for COVID-19 across developing countries with a particular focus on Africa and the implications. Front Pharmacol. 2021;11:588106. doi: 10.3389/fphar.2020.588106.

[13] Godman B, Haque M, Islam S, Iqbal S, Urmi UL, Kamal ZM, Shuvo SA, Rahman A, Kamal M, Haque M, Jahan I, Islam MZ, Hossain MM, Munzur-E-Murshid, Kumar S, Charan J, Bhatt R, Dutta S, Abhayanand JP, Sharma Y, Saleem Z, Phuong TNT, Kwon HY, Kurdi A, Wale J, Sefah I. Rapid Assessment of Price Instability and Paucity of Medicines and Protection for COVID-19 Across Asia: Findings and Public Health Implications for the Future. Front Public Health. 2020;8:585832. doi: 10.3389/fpubh.2020.585832.

[14] Sallam M, Dababseh D, Yaseen A, Al-Haidar A, Ababneh NA, Bakri FG, Mahafzah A. Conspiracy Beliefs Are Associated with Lower Knowledge and Higher Anxiety Levels Regarding COVID-19 among Students at the University of Jordan. Int J Environ Res Public Health. 2020;17(14):4915. doi: 10.3390/ijerph17144915.

[15] Vallée-Tourangeau G, Promberger M, Moon K, Wheelock A, Sirota M, Norton C, Sevdalis N. Motors of influenza vaccination uptake and vaccination advocacy in healthcare workers: development and validation of two short scales. Vaccine. 2018;36(44):6540-6545. doi: 10.1016/j.vaccine.2017.08.025.

[16] Chen IH, Ahorsu DK, Ko NY, Yen CF, Lin CY, Griffiths MD, Pakpour AH. Adapting the motors of influenza vaccination acceptance scale into the motors of COVID-19 vaccination acceptance scale: psychometric evaluation among mainland Chinese university students. Vaccine. 2021;39(32):4510-4515. doi: 10.1016/j.vaccine.2021.06.044.

[17] Thomas KW, Velthouse BA. Cognitive elements of empowerment: An "interpretive" model of intrinsic task motivation. Acad. Manag. Rev. 1990;15(4):666-681. https://doi.org/10.2307/258687

[18] Yeh YC, Chen IH, Ahorsu DK, Ko NY, Chen KL, Li PC, Yen CF, Lin CY, Griffiths MD, Pakpour AH. Measurement invariance of the drivers of COVID-19 vaccination acceptance

scale: comparison between Taiwanese and mainland Chinese-speaking populations.

Vaccines. 2021;9(3):297. doi: 10.3390/vaccines9030297.

[19] Linacre JM. FACETS Rasch measurement computer program, version 3.83.6. Chicago, IL: Winsteps.com; 2021.

[20] Boone WJ. Rasch analysis for instrument development: why, when, and how? CBE Life Sci Educ. 2016;15(4):rm4. doi: 10.1187/cbe.16-04-0148.

[21] Tennant A, Conaghan PG. The Rasch measurement model in rheumatology: what is it and why use it? When should it be applied, and what should one look for in a Rasch paper? Arthritis Rheum. 2007;57(8):1358-1362. doi: 10.1002/art.23108.

[22] Wright BD. Solving measurement problems with the Rasch model. J Educ Meas. 1977;14(2):97–116. doi: 10.1111/j.1745-3984.1977.tb00031.x

[23] Ogunleye OO, Basu D, Mueller D, Sneddon J, Seaton RA, Yinka-Ogunleye AF, Wamboga J, Miljković N, Mwita JC, Rwegerera GM, Massele A, Patrick O, Niba LL, Nsaikila M, Rashed WM, Hussein MA, Hegazy R, Amu AA, Boahen-Boaten BB, Matsebula Z, Gwebu P, Chirigo B, Mkhabela N, Dlamini T, Sithole S, Malaza S, Dlamini S, Afriyie D, Asare GA, Amponsah SK, Sefah I, Oluka M, Guantai AN, Opanga SA, Sarele TV, Mafisa RK, Chikowe I, Khuluza F, Kibuule D, Kalemeera F, Mubita M, Fadare J, Sibomana L, Ramokgopa GM, Whyte C, Maimela T, Hugo J, Meyer JC, Schellack N, Rampamba EM, Visser A, Alfadl A, Malik EM, Malande OO, Kalungia AC, Mwila C, Zaranyika T, Chaibva BV, Olaru ID, Masuka N, Wale J, Hwenda L, Kamoga R, Hill R, Barbui C, Bochenek T, Kurdi A, Campbell S, Martin AP, Phuong TNT, Thanh BN, Godman B. Response to the novel corona virus (COVID-19) pandemic across Africa: successes, challenges, and implications for the future. Front Pharmacol. 2020;11:1205. doi: 10.3389/fphar.2020.01205.

[24] Sallam M. COVID-19 Vaccine hesitancy worldwide: a concise, systematic review of vaccine acceptance rates. Vaccines. 2021;9(2):160. doi: 10.3390/vaccines9020160.

[25] Afriyie DK, Asare GA, Amponsah SK, Godman B. COVID-19 pandemic in resource-poor countries: challenges, experiences, and opportunities in Ghana. J Infect Dev Ctries. 2020;14(8):838-843. doi: 10.3855/jidc.12909.

[26] Wright BD, Linacre JM. Reasonable mean-square fit values. Rasch Meas. Trans. 1994;8(3), 370.

[27] Bond TG, Yan Z, Heene M. Applying the Rasch Model: fundamental measurement in the human sciences. 4th ed. New York (NY): Routledge; 2021.

[28] McHorney CA, Tarlov AR. Individual-patient monitoring in clinical practice: are available health status surveys adequate? Qual Life Res. 1995;4(4):293-307. doi: 10.1007/BF01593882.

[29] Zwick R, Thayer DT, Lewis C. An empirical Bayes approach to Mantel-Haenszel DIF analysis. J. Educ. Meas. 1999;36(1):1-28.

[30] Akoglu H. User's guide to correlation coefficients. Turk J Emerg Med. 2018;18(3):91-93. doi: 10.1016/j.tjem.2018.08.001.

[31] Chan YH. Biostatistics 104: correlational analysis. Singapore Med J. 2003 Dec;44(12):614-619.

[32] Harrison EA, Wu JW. Vaccine confidence in the time of COVID-19. Eur J Epidemiol. 2020;35(4):325-330. doi: 10.1007/s10654-020-00634-3.

[33] Nzaji MK, Ngombe LL, Mwamba GN, Ndala DBB, Miema JM, Lungoyo CL, Mwimba BL, Bene ACM, Musenga EM. Acceptability of vaccination against COVID-19 among healthcare

workers in the democratic republic of the Congo. Pragmat Obs Res. 2020;11:103-109. doi: 10.2147/POR.S271096.

[34] Walsh-Messinger J, Manis H, Vrabec A, Sizemore J, Bishof K, Debidda M, Malaspina D, Greenspan N. The kids are not alright: a preliminary report of post-COVID syndrome in university students. J Am Coll Health. 2021;1-7. doi: 10.1101/2020.11.24.20238261.

[35] Anthes E. (2021). Breakthrough infections are less likely to lead to long Covid, a study suggests. The New York Times. [Internet]. [updated 2021 September 1; cited 2021 September 25]; Available from: https://www.nytimes.com/2021/09/01/health/breakthrough-infections-long-covid.html?auth=link-dismiss-google1tap

[36] Graupensperger, S., Abdallah, D. A., & Lee, C. M. (2021). Social norms and vaccine uptake: College students' COVID vaccination intentions, attitudes, and estimated peer norms and comparisons with influenza vaccine. *Vaccine*, *39*(15), 2060–2067. https://doi.org/10.1016/j.vaccine.2021.03.018

[37] Browning MHEM, Larson LR, Sharaievska I, Rigolon A, McAnirlin O, Mullenbach L, Cloutier S, Vu TM, Thomsen J, Reigner N, Metcalf EC, D'Antonio A, Helbich M, Bratman GN, Alvarez HO. Psychological impacts from COVID-19 among university students: Risk factors across seven states in the United States. PLoS One. 2021;16(1):e0245327. doi: 10.1371/journal.pone.0245327.

[38] Boone WJ, Townsend JS, Staver J. Using Rasch theory to guide the practice of survey development and survey data analysis in science education and to inform science reform efforts: an exemplar utilizing STEBI self-efficacy data. Sci. Educ. 2011;95(2):258-280. doi: 10.1002/sce.20413

[39] Boone WJ, Scantlebury K. The role of Rasch analysis when conducting science education research utilizing multiple-choice tests. Sci. Educ. 2005;90:253-269.

[40] Boone WJ, Staver JR, Yale MS. Chapter 8. Fit. In Rasch Analysis in the Human Sciences. The Netherlands: Springer; 2014.

[41] Guidry JPD, Laestadius LI, Vraga EK, Miller CA, Perrin PB, Burton CW, Ryan M, Fuemmeler BF, Carlyle KE. Willingness to get the COVID-19 vaccine with and without emergency use authorization. Am J Infect Control. 2021;49(2):137-142. doi: 10.1016/j.ajic.2020.11.018.

[42] Everington K (2021). Taiwan's 1st-dose vaccination rate surpasses 30%. [Internet]. [cited 2021 September 26]; Available from: https://www.taiwannews.com.tw/en/news/4261089

[43] Mallapaty S, Callaway E. (2021). What scientists do and don't know about the Oxford–AstraZeneca COVID vaccine. [Internet]. [updated 2021 March 25; cited 2021 September 26]; Available from: https://www.nature.com/articles/d41586-021-00785-7

[44] Cohen J. (2021). South Africa suspends use of AstraZeneca's COVID-19 vaccine after it fails to clearly stop virus variant. [Internet]. [updated 2021 February 8; cited 2021 September 26]; Available from: https://www.science.org/news/2021/02/south-africa-suspends-use-astrazenecas-covid-19-vaccine-after-it-fails-clearly-stop

[45] Pastorino R, Villani L, Mariani M, Ricciardi W, Graffigna G, Boccia S. Impact of COVID-19 pandemic on flu and COVID-19 vaccination intentions among university students. Vaccines. 2021;9(2):70. doi: 10.3390/vaccines9020070.

[46] Qiao S, Friedman DB, Tam CC, Zeng C, Li X. Vaccine acceptance among college students in South Carolina: Do information sources and trust in information make a difference? medRxiv [Preprint]. 2020:2020.12.02.20242982. doi: 10.1101/2020.12.02.20242982.

[47] Cantuaria ML, Blanes-Vidal V. Self-reported data in environmental health studies: mail vs. web-based surveys. BMC Med. Res. Methodol. 2019;*19*(1):238. doi: 10.1186/s12874-019-0882-x

[48] McMaster HS, LeardMann CA, Speigle S, Dillman DA; Millennium Cohort Family Study Team. An experimental comparison of web-push vs. paper-only survey procedures for conducting an in-depth health survey of military spouses. BMC Med Res Methodol. 2017;17(1):73. doi: 10.1186/s12874-017-0337-1.

**Appendix A. Drivers of COVID-19 Vaccination Acceptance Scale.**

**English version (Items underlined are reverse-coded items) for Ghanaian**

1. Vaccination is a very effective way to protect me against the COVID-19.

   Strongly disagree (1)

   Disagree (2)

   Slightly disagree (3)

   Neither disagree nor agree (4)

   Slightly agree (5)

   Agree (6)

   Strongly agree (7)


2. I know very well how vaccination protects me from the COVID-19.

   Strongly disagree (1)

   Disagree (2)

   Slightly disagree (3)

   Neither disagree nor agree (4)

   Slightly agree (5)

   Agree (6)

   Strongly agree (7)


3. It is important that I get the COVID-19 jab.

   Strongly disagree (1)

   Disagree (2)

   Slightly disagree (3)

   Neither disagree nor agree (4)

   Slightly agree (5)

   Agree (6)

   Strongly agree (7)

4. Vaccination greatly reduces my risk of catching COVID-19.

Strongly disagree (1)

Disagree (2)

Slightly disagree (3)

Neither disagree nor agree (4)

Slightly agree (5)

Agree (6)

Strongly agree (7)

5. I understand how the flu jab helps my body fight the COVID-19 virus.

Strongly disagree (1)

Disagree (2)

Slightly disagree (3)

Neither disagree nor agree (4)

Slightly agree (5)

Agree (6)

Strongly agree (7)

6. The COVID-19 jab plays an important role in protecting my life and that of others.

Strongly disagree (1)

Disagree (2)

Slightly disagree (3)

Neither disagree nor agree (4)

Slightly agree (5)

Agree (6)

Strongly agree (7)

7. I feel under pressure to get the COVID-19 jab.

   Strongly disagree (7)

   Disagree (6)

   Slightly disagree (5)

   Neither disagree nor agree (4)

   Slightly agree (3)

   Agree (2)

   Strongly agree (1)


8. The contribution of the COVID-19 jab to my health and well-being is very important.

   Strongly disagree (1)

   Disagree (2)

   Slightly disagree (3)

   Neither disagree nor agree (4)

   Slightly agree (5)

   Agree (6)

   Strongly agree (7)


9. I can choose whether to get a COVID-19 jab or not.

   Strongly disagree (1)

   Disagree (2)

   Slightly disagree (3)

   Neither disagree nor agree (4)

   Slightly agree (5)

   Agree (6)

   Strongly agree (7)


10. How the COVID-19 jab works to protect my health is a mystery to me.

Strongly disagree (7)

Disagree (6)

Slightly disagree (5)

Neither disagree nor agree (4)

Slightly agree (3)

Agree (2)

Strongly agree (1)

11. I get the COVID-19 jab only because I am required to do so.

Strongly disagree (7)

Disagree (6)

Slightly disagree (5)

Neither disagree nor agree (4)

Slightly agree (3)

Agree (2)

Strongly agree (1)

12. Getting the COVID-19 jab has a positive influence on my health.

Strongly disagree (1)

Disagree (2)

Slightly disagree (3)

Neither disagree nor agree (4)

Slightly agree (5)

Agree (6)

Strongly agree (7)

**Traditional Chinese version (Items underlined are reverse-coded items) for Taiwanese**

1.「我打新冠肺炎疫苗是為了保護自己不受感染。」

□ □ □ □ □ (1)

□ □ □ □ (2)

□ □ □ □ □ □ (3)

□ □ □ □ □ □ □ □ (4)

□ □ □ □ □ (5)

□ □ □ (6)

□ □ □ □ (7)


2.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ 。」

□ □ □ □ □ (1)

□ □ □ □ (2)

□ □ □ □ □ □ (3)

□ □ □ □ □ □ □ □ (4)

□ □ □ □ □ (5)

□ □ □ (6)

□ □ □ □ (7)


3.「□ □ □ □ , □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ 。」

□ □ □ □ □ (1)

□ □ □ □ (2)

□ □ □ □ □ □ (3)

□ □ □ □ □ □ □ □ (4)

□ □ □ □ □ (5)

□ □ □ (6)

□ □ □ □ (7)


4.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ 。」

□ □ □ □ □ (1)

□ □ □ □ (2)

□ □ □ □ □ (3)

□ □ □ □ □ □ □ □ (4)

□ □ □ □ □ (5)

□ □ □ (6)

□ □ □ □ (7)


5.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ 。」

□ □ □ □ □ (1)

□ □ □ □ (2)

□ □ □ □ □ (3)

□ □ □ □ □ □ □ □ (4)

□ □ □ □ □ (5)

□ □ □ (6)

□ □ □ □ (7)


6.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ 。」

□ □ □ □ □ (1)

　□ □ □ □　(2)

　□ □ □ □ □　(3)

　□ □ □ □ □ □ □　(4)

　□ □ □ □ □　(5)

　□ □ □　(6)

　□ □ □ □　(7)


7.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □。」

　□ □ □ □ □　(7)

　□ □ □ □　(6)

　□ □ □ □ □ □　(5)

　□ □ □ □ □ □ □ □　(4)

　□ □ □ □ □　(3)

　□ □ □　(2)

　□ □ □ □　(1)


8.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □。」

　□ □ □ □ □　(1)

　□ □ □ □　(2)

　□ □ □ □ □ □　(3)

　□ □ □ □ □ □ □ □　(4)

　□ □ □ □ □　(5)

　□ □ □　(6)

□ □ □ □ (7)

9.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □。」

　□ □ □ □ □ (1)

　□ □ □ □ (2)

　□ □ □ □ □ (3)

　□ □ □ □ □ □ □ (4)

　□ □ □ □ □ (5)

　□ □ □ (6)

　□ □ □ □ (7)

10.「□ □ □ □ □ □ □ □ □ □ □ □ □，□ □ □ □ □ □ □。」

　□ □ □ □ □ (7)

　□ □ □ □ (6)

　□ □ □ □ □ (5)

　□ □ □ □ □ □ □ (4)

　□ □ □ □ □ (3)

　□ □ □ (2)

　□ □ □ □ (1)

11.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □。」

　□ □ □ □ □ (7)

　□ □ □ □ (6)

　□ □ □ □ □　(5)

　□ □ □ □ □ □ □　(4)

　□ □ □ □ □　(3)

　□ □ □　(2)

　□ □ □ □　(1)


12.「□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □。」

　□ □ □ □ □　(1)

　□ □ □ □　(2)

　□ □ □ □ □ □　(3)

　□ □ □ □ □ □ □ □　(4)

　□ □ □ □ □　(5)

　□ □ □　(6)

　□ □ □ □　(7)