Assessment of the accuracy of a new tool for the screening of smartphone addiction

Julia Machado Khoury¹,²☯, André Augusto Corrêa de Freitas¹☯, Marco Antônio Valente Roque¹☯, Maicon Rodrigues Albuquerque³☯, Maila de Castro Lourenço das Neves¹☯, Frederico Duarte Garcia¹,²,⁴,⁵*  

¹ Department of Mental Health, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, ² Post-graduation Program in Molecular Medicine, School of Medicine, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, ³ Department of Sports, School of Physical Education, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, ⁴ National Institute of Science and Technology of Molecular Medicine, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, ⁵ Unité Inserm, Rouen, France

☯ These authors contributed equally to this work.

* frederico.garciafd@gmail.com

Abstract

Objective
To translate, adapt and validate the Smartphone Addiction Inventory (SPAI) in a Brazilian population of young adults.

Method
We employed the translation and back-translation method for the adaptation of the Brazilian version SPAI (SPAI-BR). The sample consisted of 415 university students. Data was collected through an electronic questionnaire, which consisted of the SPAI-BR and the Goodman Criteria (gold standard). The retests were carried out 10–15 days after the initial tests with 130 individuals.

Results
The SPAI-BR maintained semantic, idiomatic and conceptual equivalences from the original scale. The Confirmatory Factor Analysis confirmed the One-factor model of the SPAI with good fit indexes (χ² = 767.861, CFI = 0.913, TLI = 0.905, RMSE = 0.061, WRMR = 1.465). The Kuder-Richardson Coefficient showed good internal consistency. The analysis of the ROC curve established an area under the curve of 86.38%. The Intraclass-Correlation Coefficient of 0.926 between the test and the retest demonstrated an excellent temporal stability. The high correlation between SPAI-BR and the Goodman Criteria (rs = 0.750) established the convergent validity.

Conclusion
The SPAI-BR is a valid and reliable tool for the detection of Smartphone Addiction in Brazilian university students.
Introduction

Smartphones are essential tools in our everyday life. They provide applications for communication, information, education, and entertainment. They have also been used for data collection, to prevent and treat psychiatric disorders, chronic diseases and to improve elders’ quality of life [1–9]. Although smartphones can improve many aspects of our lives, excessive use may be associated to smartphone addiction [10–13].

Smartphone addiction is a technological addiction, defined by Griffiths as a behavioral addiction that involves human-machine interaction [14]. Several authors have described the presence of addiction symptoms in subjects presenting a problematic use or diagnosed with smartphone addiction. Among these, the most commonly described were withdrawal symptoms (i.e. anxiety, irritability, and impatience) [11–13, 15–19]; loss of control in using smartphones [15, 20]; a longer time of use than initially intended [10–13]; tolerance [11–13, 19]; interference in activities of daily living [10–13, 19, 21]; positive anticipation [11, 18, 19, 22]; and maintenance of the amount of use despite negative consequences [21].

Studies in several countries reported a high prevalence of smartphone addiction, especially among university students. The prevalence of smartphone addiction in young students is estimated at 6% in Italy [23]; 38% in Spain [16]; 18.8% in Japan [24]; 28.7% in the Netherlands [25]; 27.4% in Hong Kong [26]; 25% in the United States [27]; 44% in India [28]; 25.8% in Jordan [29]; and 67% in the United Arab Emirates [30].

In terms of negative consequences, the diagnosis of smartphone addiction is associated with sleep disorders [31–33]; depressive and anxious symptoms [31, 33–36]; and reduction of academic and labor performance [37, 38].

Although no specific diagnostic criteria for smartphone addiction exist, the study of this disorder seems to be an important issue. Screening instruments are important as they are a first step to the phenotyping process of research. No validated instrument for the screening of smartphone addiction is available in Brazil. Around the globe, the “Smartphone Addiction Scale” (SAS) [11] and, the “Smartphone Addiction Inventory” (SPAI) are the most frequently used screening instruments [39]. We opted to validate the SPAI questionnaire, because it is shorter and easier to respond, therefore, more suitable to be used in the Brazilian public health care system.

The main aim of this study was to validate the SPAI for use in the Brazilian population. We hypothesize that a Brazilian version of the SPAI (SPAI-BR) is a valid tool for the screening of smartphone addiction in Brazilian young adults.

Materials and methods

Study design and ethical aspects

This was a cross-sectional and prospective study for the assessment of psychometric features of the Brazilian version of the Smartphone Addiction Inventory. The Committee of Ethics in Research of the Federal University of Minas Gerais (UFMG) approved this study (CAAE 54066516.0.0000.5149). Participants provided their written informed consent about the voluntary nature of the study, its risks, and its benefits. This study did not include minors and it was carried out in accordance with the latest version of the Declaration of Helsinki.

Setting and sample

This study was developed at the Universidade Federal de Minas Gerais (UFMG) from March to June of 2016. We recruited a convenience sample of students from different graduate courses at UFMG.
All undergraduate students that have a smartphone with all day internet access (e.g. 3G, 4G or Wi-Fi), excluding subjects with visual or hearing impairment, were eligible to participate. We based the sample profile on previously recognized risk factors for smartphone addiction [16, 23, 25–28, 30, 40, 41].

We calculated the sample size based on the recommendations of Hair et al. [42], to use at least 10 times the number of subjects for each item on the scale. As the SPAI has 26 items, the calculated sample for this study was of 450 individuals. The retest sample size calculation was based on the study of correlations of Faraggi and Reiser [43]. According to the recommendation of these authors, the sample size calculation for correlation studies should consider the probability of type I error, the probability of type II error and the hypothetical value of the expected correlation coefficient in the study. For a correlation coefficient of 0.60 (good correlation) and considering the probabilities of occurrence of type I error (0.05) and type II error (0.10), each group should be composed of a minimum of 25 subjects, totaling a minimum of 50 individuals who undergo the test-retest. We estimated a sample size of 150 subjects for retest because the non-response rate in previous studies, assessing retest by e-mail, presented a non-response rate of 60 to 70% [44].

Instruments

**Smartphone Addiction Inventory (SPAI).** Lin and Chang developed and validated the SPAI for the screening of Smartphone Addiction in a Taiwanese sample of graduate students in 2014 [39]. Authors based the SPAI on the "Chen Internet Addiction Scale" (CIAS) [45]. In summary, the term “internet" in the CIAS was replaced by “smartphone" and authors added one question to assess the use of smartphone while driving or crossing the street. The original SPAI has 26 items in Likert format. The Cronbach Alpha value of the entire scale is 0.94 and for the four subscales, “compulsive behavior”, “functional impairment”, “withdrawal syndrome” and “tolerance syndrome” it is 0.87, 0.88, 0.81 and 0.72, respectively.

Pavia et al. (2016) translated, adapted and validated an Italian version of the SPAI in a sample of 485 college students from the University of Palermo in Sicily [46]. Non-validated versions of the SPAI have been used in South Korea and Spain [47, 48].

**Goodman's criteria.** Due to the lack of a specific diagnostic criteria for smartphone addiction, we used Goodman’s Criteria for addictions as the gold standard for this study [49]. Goodman’s Criteria were used as a basis for the construction of addictive disorders’ diagnostic criteria of ICD-10 [50] and DSM-5 [51] and they have been widely used in an interview format by specialists to diagnose dependency syndromes [49, 52–59]. Previous validation studies of screening instruments for behavioral addictions that did not have specific diagnostic criteria employed Goodman’s criteria as the gold standard [52–55, 57, 59].

**Translation and cultural adaptation of the SPAI**

The SPAI was translated into Brazilian Portuguese language and edited for syntax and content by five experts on addictions. After adjustments, it was back translated by a native English speaker linguist. Original and back-translated versions were reviewed, compared and adjusted for equivalence by consensus among the study team and the linguist. Additional editing of the Brazilian version of the SPAI (SPAI-BR) was made to improve the understanding of the questions after a pilot study performed on a group of 10 students. Moreover, we opted to use a dichotomic version of the SPAI-BR in order to decrease time of completion and increase efficiency for its use in health surveys. Finally, we performed a second pilot test with 40 graduate students using the final version of the SPAI-BR to assess mean time of questionnaire completion.
Data collection

The final questionnaire was composed of three sections: 1. demographic data: gender, race, birth date, marital status, and family income; 2. SPAI-BR; and 3. Goodman’s Criteria. For data collection, we used an electronic data collection system based on tablet computers. In sum, we transferred the whole questionnaire to the web-based platform iSurvey (HarvestYourData, CA) and installed the software on tablet computers. Respondents completed the demographic questionnaire and the SPAI-BR (self-applied) and handed the tablet to a psychiatrist who performed a structured interview assessing Goodman’s Criteria. Data was uploaded through Wi-Fi, transmitted to a database and exported to SPSS format (IBM Corporation, CA). Data bank in SPSS format can be seen in S1 File.

Statistical analysis

In the descriptive analysis, we calculated mean, standard deviation, median, quartiles and minimum/maximum for continuous variables. For categorical variables, we calculated frequency and proportion. Data normality was assessed using Kolmogorov-Smirnov test.

Factorial structure of the SPAI-BR was evaluated using Confirmatory Factor Analysis (CFA). We used the Weighted Least Squares Mean and Variance estimator (WLSMV) as a method for parameter estimation. Model fit was assessed considering the following fit indexes: Chi-square ($\chi^2$), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error (RMSE) and Weighted Root Mean Square Residual (WRMR). The overall model fit was judged using the following cutoff values: for the CFI and TLI, values larger than 0.90 are considered indicators of acceptable fit [60–62]; for the RMSE, values smaller than 0.05 indicate good fit and values between 0.05 and 0.08 indicate acceptable model fit [63]; for the WRMR, a cutoff value close to 1.00 is considered suitable [64]. Preliminarily Kaiser-Meyer-Olkin (KMO) and Bartlett Test of Sphericity were used to examine the factorability of the data. Internal consistency was computed using Kuder-Richardson Coefficient for the total scale and for the dimensions extracted by factor analysis.

To calculate correlation between the scores of the SPAI-BR at different times (test-retest) we used the Intraclass-Correlation Coefficient, which indicates temporal stability of the instrument. Correlations were evaluated according to the following values: less than 0.40 –poor correlation; 0.41 to 0.60 –moderate correlation; 0.61 to 0.80 –good correlation; and 0.81 to 1.00 –excellent correlation [65].

Several "Receiver Operating Characteristic" (ROC) curves were constructed to evaluate the SPAI-BR and its sensitivity, specificity, positive predictive value and negative predictive value at different levels of prevalence.

Additionally, to derive optimal cut-off scores, decision theory was used as Smits and colleagues have proposed for mental health screening [66, 67]. Medical costs were included in our analyses of relative costs considering that expenses in a mental health setting will be similar for patients with smartphone addiction (67). Using the proportional costs of correct and erroneous screening results and the rates of these correct and erroneous screening results according to prevalence, we calculated relative costs for each cut-off point, with the formula:

$$\text{cost} = (C_{TP} \times P_{TP}) + (C_{TN} \times P_{TN}) + (C_{FP} \times P_{FP}) + (C_{FN} \times P_{FN})$$

In this formula, “cost” represents total medical costs, $C_{TP}$ stands for the costs of each true positive, and $P_{TP}$ represents the probability of true positives (according to the levels of prevalence, specificity and sensibility). Subsequently, costs and probabilities are analyzed for true negatives (TN), false positives (FP) and FN (false negatives). We calculated relative costs with
the proportions of expenses for true positives (0.89), true negatives (0.001), false positives (0.03) and false negatives (1.0) as described by Smits and colleagues [66, 67].

As proposed by decision theory, the optimal cut-off point was chosen according to lowest expected costs.

To determine the convergent validity between SPAI-BR and Goodman’s Criteria we calculated the Spearman Correlation Coefficient for the total scale and the factors.

In this study, each subject responded a questionnaire on an electronic platform, and the non-response of an item precluded the progression to the next items. For this reason, our database did not include missing values.

Analyses were performed in STATA 12.1 software (Stata Corporation, College Station, Texas) and MPLUS version 6.12.

Results

Translation and cultural adaptation

The translation and cultural adaptation led to an instrument in Brazilian Portuguese that kept the semantic (meaning of words), idiomatic (meaning of expressions) and conceptual (meaning of concepts) equivalences from the original scale. The original scale and the translated scale are represented in S1 Table.

Sample description

At endpoint, we assessed 415 subjects, and retested 130 individuals at 10 to 15 days (Mean = 12.619 ± 1.593) after the initial test. The demographic characteristics of the sample are described in Table 1. In the entire sample, the prevalence of smartphone addiction is 35.66%

Table 1. Sample demographic characteristics (n = 415).

| Parameter                      | n  | %    |
|-------------------------------|----|------|
| Gender                        |    |      |
| Female                        | 226| 54.5 |
| Male                          | 189| 45.5 |
| Age                           |    |      |
| 18 to 25                      | 321| 77.3 |
| 26 to 35                      | 94 | 22.7 |
| Marital status                |    |      |
| Married                       | 21 | 5.1  |
| Unmarried                     | 394| 94.9 |
| Skin color                    |    |      |
| Indian                        | 10 | 2.4  |
| White                         | 252| 60.7 |
| Black                         | 19 | 4.6  |
| Brown                         | 116| 28.0 |
| Did not answer                | 18 | 4.3  |
| Monthly family income         |    |      |
| No income                     | 7  | 1.7  |
| Up to R$880.00                | 10 | 2.4  |
| From R$880.00 to R$2,640.00   | 55 | 13.3 |
| From R$2,640.00 to R$5,280.00 | 71 | 17.1 |
| From R$5,280.00 to R$7,920.00 | 65 | 15.7 |
| From R$7,920.00 to R$10,560.00| 52 | 12.5 |
| From R$10,560.00 to R$13,200.00| 34 | 8.2  |
| From R$13,200.00 to R$17,600.00| 38 | 9.2  |
| Above R$17,600.00             | 43 | 10.4 |
| Do not know/did not answer    | 40 | 9.6  |

https://doi.org/10.1371/journal.pone.0176924.t001
(n = 148) according to Goodman’s Criteria. The flow diagram and the cross tabulation of the index test results by the results of the gold standard can be seen in S1 Fig.

Confirmatory factor analysis

The goodness of fit, assessed by the KMO, was of 0.901, and the Bartlett’s Sphericity Test resulted in 2964.30 (p < 0.001), considering the 26 questions. The responses of the SPAI-BR were not normally distributed according to the Kolmogorov-Smirnov Test (p < 0.001), therefore, we used the method of weighted least squares and adjusted variance (WLSMV) for the Confirmatory Factor Analysis (CFA). Moreover, for the CFA we considered four factors with oblique rotation, as previously described in the original validation study of the SPAI. Both models resulted in a good fit index, as can be seen in Table 2 and in the CFA path diagram in Fig 1.

Internal consistency

The Kuder-Richardson Coefficient of the One-factor model was 0.887. Moreover, the Kuder-Richardson Coefficient of the Four-factor model was 0.738 for ‘Compulsive Behavior’; 0.736 for ‘Functional Impairment’; 0.753 for ‘Withdrawal’; and 0.481 for ‘Tolerance’. Since the ‘Tolerance’ factor has shown low internal consistency (less than 0.7), the One-factor structure is more adequate for SPAI-BR.

Temporal stability

We retested 130 subjects after 10 to 15 days (Mean = 12.619 ± 1.593) from the initial test. The Intraclass Correlation Coefficient (ICC) was 0.926, indicating an excellent positive correlation between test and retest (F = 27.55, p < 0.01). The temporal stability of the SPAI-BR is presented in S2 Table.

Criterion validity

Criterion validity was established through the comparison between SPAI-BR and the Goodman Criteria (the gold standard used in the study). We ran ROC curves considering the

![Fig 1. Confirmatory factor analysis’s path diagram. F1: ‘Compulsive Behavior’; F2: ‘Functional Impairment’; F3: ‘Withdrawal’; F4: ‘Tolerance’; SPAI 1–26, correspond to each of the SPAI-BR questions, respectively.](https://doi.org/10.1371/journal.pone.0176924.g001)
prevalence of smartphone addiction in our study (35.66%) and considering other approximate prevalences that have been found in the literature (5%; 10%, 20% and 40%) (S3 Table). The ROC curve for the prevalence found in our study (S2 Fig.) has an area under the curve of 86.38% (standard error 0.0183), meaning that the SPAI-BR has good accuracy in our population [68]. In general, higher AUC values indicate better test performance [69].

At the prevalence found in our study (35.66%), the optimal cut-off point with the lowest costs was seven. At this cut-off, sensitivity was 90.54%, specificity was 59.93%, PPV was 55.6, NPV was 92.0% and accuracy was 70.85%. Additional cost estimates relative to different prevalences found in the literature are displayed in S4 Table.

Convergent validity

In the convergent validity analysis, the correlations between the SPAI-BR score and Goodman Criteria score were examined. The SPAI-BR total score was found to have a positive correlation with the Goodman Criteria total score at Spearman’s rho of 0.751. The correlations between the SPAI-BR subscales and the Goodman Criteria total score ranged from 0.548 to 0.709, indicating a statistically significant positive correlation (p < 0.01). Table 3 shows the values of convergent validity.

Discussion

The purpose of this study was to translate the English version of an instrument for smartphone addiction screening, the SPAI, into Brazilian Portuguese and achieve cultural adaptation and validation of this Brazilian version (SPAI-BR). Our results demonstrated a good validity and reliability of the SPAI-BR for the detection of Smartphone addiction in a Brazilian population of young adults.

In this study, we validated a dichotomic (i.e. “yes”; “no”) version of the questionnaire, aiming for reduction in completion time and making the SPAI-BR more suitable for the Brazilian population. This procedure has been questioned in the literature since dichotomic format may decrease the instrument’s sensitivity and its internal consistency [70]. However, some studies have shown that dichotomous format is of more rapid application and easier to understand [44, 70, 71]. Therefore, this format seems to be more appropriate for populations with low socio-economic-cultural level, as is characteristic in much of the Brazilian population. Furthermore, our results demonstrated that the SPAI-BR provided an internal consistency and a sensitivity comparable to the original version of the questionnaire, even in a dichotomic version [39].

Table 3. Spearman Correlation Coefficients between the total SPAI-BR, the SPAI-BR’s factors and the Goodman Criteria (n = 415).

|        | Goodman | Factor 1 | Factor 2 | Factor 3 | Factor 4 | SpaTotal |
|--------|---------|----------|----------|----------|----------|----------|
| Goodman | 1       |          |          |          |          |          |
| Factor 1 | 0.7093  | 1        |          |          |          |          |
| Factor 2 | 0.5528  | 0.6125   | 1        |          |          |          |
| Factor 3 | 0.6264  | 0.6924   | 0.4969   | 1        |          |          |
| Factor 4 | 0.5481  | 0.5705   | 0.4467   | 0.5225   | 1        |          |
| SpaTotal | 0.7508  | 0.9047   | 0.7699   | 0.8504   | 0.7078   | 1        |

Note: Factor 1: “Compulsive Behavior”, Factor 2: “Functional Impairment”, Factor 3: “Withdrawal”, Factor 4: “Tolerance”. All correlations are significant for p < 0.001.

https://doi.org/10.1371/journal.pone.0176924.t003
We performed the Confirmatory Factor Analysis (CFA) in our dataset to assess if our instrument presented a factorial structure similar to the original SPAI [72, 73]. CFA showed good model fit indexes for both the one-factor model and the Four-factor model. However, the ‘Tolerance’ factor presented a lower index of internal consistency (less than 0.7). The adequacy of the presence of tolerance for the diagnosis and for the screening of smartphone addiction has been questioned. It is controversial whether tolerance is a core symptom of smartphone addiction. "Tolerance" is the factor with the most unstable structure, the smallest eigenvalue, and the fewest number of items in most smartphone addiction questionnaires [11, 39, 74]. Additionally, tolerance in smartphone addiction is difficult to measure, since smartphone use is carried out for short periods of time, with great frequencies, and the total time of use is very inaccurately self-reported. Smartphones have also become essential to current lifestyles. Therefore, increased smartphone use may not be pathological, but rather a necessity for functional communication.

Besides all the reasons above, we attribute the low internal consistency of the “tolerance” factor to the fact that we have converted the original Likert instrument into a dichotomous format and because the ‘Tolerance’ factor is formed by only three items. Internal consistency is normally influenced by both factors, as demonstrated in previous studies [72, 73]. Kline [75] suggests that values lower than 0.7 are expected and acceptable in psychological constructs because of the diversity of the structures being measured. Moreover, Streiner (2003) estimates that, although an internal consistency coefficient of 0.40 may be considered insufficient for diagnostic tests, it is acceptable for screening tests. We opted to consider the one-factor SPAI-BR more appropriate for screening, as there is no consensus regarding the suitability of the internal consistency of less than 0.7 in these cases. Furthermore, the one-factor structure demonstrated optimal internal consistency (KR = 0.887) and good model fit indexes ($\chi^2 = 767.861; \text{CFI} = 0.913, \text{TLI} = 0.905, \text{RMSE} = 0.061; \text{WRMR} = 1.465$), and it does not change the clinical applicability of the instrument.

The temporal stability of the SPAI-BR was excellent (ICC = 0.926), which shows the reliability of the instrument. In addition, the positive correlation between the SPAI-BR and the Goodman Criteria (Spearman’s rho = 0.751) indicated that both instruments allow the detection of the same construct, establishing the convergent validity of the SPAI-BR.

Regarding the determination of possible cutoff points for SPAI-BR, some considerations must be made. The choice of a cutoff point will depend on the purpose of the instrument (diagnosis or screening) and the prevalence of smartphone addiction in the population in which the test will be applied. In addition, no cutoff point has full accuracy, so diagnostic errors will always occur.

The decision theory approach considers costs and benefits of correct and incorrect classifications through the screening instrument [66, 67]. Some authors have attempted to analyze these costs from a series of perspectives such as a respondent perspective, a health service provider perspective, a societal perspective and a research perspective [66, 67, 76, 77]. Economically speaking, the health care provider and the societal perspective can prove more interesting. However, since there is no previous reference to the costs of smartphone addiction, for the purposes of cost analyses, we limited ourselves to the medical costs of smartphone addiction, assuming that these can be generalized in a mental health setting [67].

We must consider that both correct and incorrect classifications by a screening instrument will incur in medical costs. Lower cutoff points cause more false positives, increasing direct treatment costs. Higher cutoff points generate more false negatives, harming many ill individuals who will not be treated. In this sense, we used the same proportions of costs of screening and treatment in a mental health setting as established by Smits and colleagues [66, 67]. In our population, with prevalence of 35.66%, the lowest costs are found at a cut-off point of seven.
For this optimal cutoff point, sensitivity was 90.54%, much greater than specificity (59.93%), and, although specificity can be considered low, this is adequate for a screening instrument [43]. Additionally, the cut-off point of seven has a high accuracy (70.85%) in our population. Investigators and clinicians may consider a distinct cut-off point according to the expected prevalence and estimated costs in their target population, as displayed in S4 Table.

One possible limitation of this study was the fact that it was carried out with a convenience sample composed of UFMG students, and therefore it could be expected that the application of this same instrument in a community sample would present different results. Therefore, data from this study cannot be generalized to other populations. However, the instrument validation process is continuous and, generally, its initial phase is carried out with the population at greater risk for the construct under analysis. Future studies with heterogeneous populations are required so that SPAI-BR will be considered valid for application across the general population.

Another limitation concerns the gold standard used to diagnose smartphone addiction in this study. The lack of a validated gold standard for the screening of smartphone addiction may compromise the accuracy of criterion validity of the SPAI-BR. However, Goodman’s Criteria is the best approximation of a gold standard, as is very similar to the diagnostic criteria for addictions in DSM 5 and ICD 10.

In conclusion, present data confirms that SPAI-BR is accurate and reliable for the quick and easy detection of patients with smartphone addiction in a Brazilian population of university students. Further studies should validate the SPAI-BR in other populations, such as children, elderly and clinical populations.

Supporting information

S1 Fig. Flow diagram and cross tabulation of the index test results by the results of the gold standard.
(DOCX)

S2 Fig. ROC curve of SPAI-BR.
(DOCX)

S1 Table. Original version and the Brazilian Portuguese adapted version of the SPAI.
(DOCX)

S2 Table. Spearman Correlation Coefficient between test and retest for the total SPAI-BR and the SPAI-BR’s factors (n = 130). Note: T1 = test of the factor “compulsive behavior”, T2 = test of the factor “functional impairment”, T3 = test of the factor “withdrawal”, T4 = test of the factor “tolerance”, TT = test of the total SPAI-BR, R1 = retest of the factor “compulsive behavior”, R2 = retest of the factor “functional impairment”, R3 = retest of the factor “withdrawal”, R4 = retest of the factor “tolerance”, RT = retest of the total SPAI-BR.
(DOCX)

S3 Table. Psychometric values for SPAI-BR at each cut-off point taking into account different prevalences of smartphone addiction. Note: CI = confidence interval; +PV = Positive Predictive Value; -PV = Negative Predictive Value.
(DOCX)

S4 Table. Relative costs associated with specific prevalences and optimal cut-off points.
(DOCX)

S1 File. Data bank.
(SAV)
Author Contributions

Conceptualization: JMK AACF MAVR MRA MCLN FDG.
Data curation: JMK AACF MAVR MRA MCLN FDG.
Formal analysis: JMK AACF MAVR MRA MCLN FDG.
Funding acquisition: FDG.
Investigation: JMK MRA FDG.
Methodology: JMK AACF MRA FDG.
Project administration: JMK AACF MAVR MRA MCLN FDG.
Resources: JMK MCLN FDG.
Software: JMK AACF MRA FDG.
Supervision: JMK MRA MCLN FDG.
Validation: JMK MAVR MRA FDG.
Visualization: JMK AACF MAVR MRA FDG.
Writing – original draft: JMK AACF MAVR FDG.
Writing – review & editing: JMK AACF MRA FDG.

References

1. Jospe MR, Fairbairn KA, Green P, Perry TL. Diet app use by sports dietitians: a survey in five countries. JMIR mHealth and uHealth. 2015; 3(1).
2. Del Favero S, Place J, Kropp J, Messori M, Keith-Hynes P, Visentin R, et al. Multicenter outpatient dinner/overnight reduction of hypoglycemia and increased time of glucose in target with a wearable artificial pancreas using modular model predictive control in adults with type 1 diabetes. Diabetes, Obesity and Metabolism. 2015; 17(5):468–76. https://doi.org/10.1111/dom.12440 PMID: 25600304
3. Trivedi D. Cochrane review summary: smartphone and tablet self-management apps for asthma. Primary health care research & development. 2015; 16(02):111–3.
4. Ubhi HK, Michie S, Kotz D, Wong WC, West R. A mobile app to aid smoking cessation: Preliminary evaluation of SmokeFree28. Journal of medical Internet research. 2015; 17(1).
5. BK W. Interreality: the experiential use of technology in the treatment of obesity. Clinical Practice & Epidemiology in Mental Health. 2011; 7(1).
6. Hebden L, Balestracci K, McGecheon K, Denney-Wilson E, Harris M, Bauman A, et al. ‘TXT2BFIT’ a mobile phone-based healthy lifestyle program for preventing unhealthy weight gain in young adults: study protocol for a randomized controlled trial. Trials. 2013; 14(1):75.
7. Lyzwinski LN. A systematic review and meta-analysis of mobile devices and weight loss with an intervention content analysis. Journal of personalized medicine. 2014; 4(3):311–85. https://doi.org/10.3390/jpm4030311 PMID: 25563356
8. Schulte M, Liang D, Wu F, Lan Y-C, Tsay W, Du J, et al. A Smartphone Application Supporting Recovery from Heroin Addiction: Perspectives of Patients and Providers in China, Taiwan, and the USA. Journal of Neuroimmunne Pharmacology. 2016:1–12.
9. Zhang MW, Ho RC. Tapping onto the potential of Smartphone applications for psycho-education and early intervention in Addictions. Frontiers in psychiatry. 2016; 7.
10. Chólich M. Mobile-phone addiction in adolescence: the test of mobile phone dependence (TMD). Prog Health Sci. 2012; 2(1):33–44.
11. Kwon M, Lee J-Y, Won W-Y, Park J-W, Min J-A, Hahn C, et al. Development and validation of a smartphone addiction scale (SAS). PloS one. 2013; 8(2):e56936. https://doi.org/10.1371/journal.pone.0056936 PMID: 23468893
12. Park WK. Mobile phone addiction. Mobile communications: Springer; 2005. p. 253–72.
13. Perry SD, Lee KC. Mobile phone text messaging overuse among developing world university students. Communication. 2007; 33(2):63–79.

14. Griffiths M. Gambling on the Internet: A brief note. Journal of Gambling Studies. 1996; 12(4):471–3. https://doi.org/10.1007/BF01539190 PMID: 24234164

15. Chóliz M. Mobile phone addiction: a point of issue. Addiction. 2010; 105(2):373–4.

16. Protegí. Seguridad infantil y costumbres de los menores en la telefonía móvil. 2005.

17. Gras ME, Cunill M, Sullman MJ, Planes M, Aymerich M, Font-Mayolás S. Mobile phone use while driving in a sample of Spanish university workers. Accid Anal Prev. 2007; 39(2):347–55. https://doi.org/10.1016/j.aap.2006.08.006 PMID: 17034749

18. James D, Drennan J, editors. Exploring addictive consumption of mobile phone technology. Australian and New Zealand Marketing Academy conference, Perth, Australia; 2005.

19. Walsh SP, White KM, Young RM. Over-connected? A qualitative exploration of the relationship between Australian youth and their mobile phones. Journal of adolescence. 2008; 31(1):77–92. https://doi.org/10.1016/j.adolescence.2007.04.004 PMID: 17560644

20. Etoe S, Toda M, Yoshimura K, Naritomi A, Den R, Morimoto K. Relationships of personality and lifestyle with mobile phone dependence among female nursing students. Social Behavior and Personality: an international journal. 2009; 37(2):231–8.

21. Casey BM. Linking psychological attributes to smartphone addiction, face-to-face communication, present absence and social capital. The Chinese University of Hong Kong; 2012.

22. Jeong S-H, Kim H, Yum J-Y, Hwang Y. What type of content are smartphone users addicted to?: SNS vs. games. Computers in Human Behavior. 2016; 54:10–7.

23. Martino G, Villetta C, Di Thiene D, Di Nicola M, Bria P, Conte G, et al. Problematic mobile phone use in adolescence: a cross sectional study. Journal of Public Health2011. p. 545–51.

24. Toda M, Monden K, Kubo K, Morimoto K. Mobile phone dependence and health-related lifestyle of university students. Social Behavior and Personality2006. p. 1277–84.

25. Leung L. Leisure boredom, sensation seeking, self-esteem, addiction symptoms and patterns of cell phone use. Mediated interpersonal communication2007. p. 359–81.

26. Leung L. Linking psychological attributes to addiction and improper use of the mobile phone among adolescents in Hong Kong. Journal of children and Media2008. p. 93–113.

27. Smetaniuk P. A preliminary investigation into the prevalence and prediction of problematic cell phone use. J Behav Addict. 2014; 3(1):41–53. PubMed Central PMCID: PMCPMC4117273. https://doi.org/10.1556/JBA.3.2014.004 PMID: 25215213

28. Davey S, Davey A. Assessment of Smartphone Addiction in Indian Adolescents: A Mixed Method Study by Systematic-review and Meta-analysis Approach. Int J Prev Med. 2014; 5(12):1500–11.; PubMed Central PMCID: PMCPMC4336980. PMID: 25707985

29. Abu-Jedy A. Mobile phone addiction and its relationship with self-discloser among sample of students from University Of Jordan And Amman Al-Ahliyya University. Jordan Journal of educational science. 2008; 4(2):137–50.

30. Halayem S, Nouira O, Bourgou S, Bouden A, Othman S, Halayem M. Le téléphone portable: une nouvelle addiction chez les adolescents. La Tunisie Medicaile2010. p. 593–6.

31. Thomée S, Härenstam A, Hagberg M. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults—a prospective cohort study. BMC public health. 2011; 11(1):1.

32. Lee KC, Perry SD. Student instant message use in a ubiquitous computing environment: Effects of deficient self-regulation. Journal of Broadcasting & ElectronicMedia2004. p. 399–420.

33. Demirci K, Akdoğan M, Akpinar A. Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students. Journal of behavioral addictions. 2015; 4(2):85–92. https://doi.org/10.1556/2006.4.2015.010 PMID: 26132913

34. Ha JH, Chin B, Park DH, Ryu SH, Yu J. Characteristics of excessive cellular phone use in Korean adolescents. CyberPsychology & Behavior2008. p. 783–4.

35. Babadi-Akashe Z, Zamani BE, Abedini Y, Akbari H, Hedayati N. The Relationship between Mental Health and Addiction to Mobile Phones among University Students of Shahrekord, Iran. Addict Health. 2014; 6(3):93–9. PubMed Central PMCID: PMCPMC4354275. PMID: 25984275

36. Choi S-W, Kim J-D, Choi J-S, Ahn H, Choi E-J, Song W-Y, et al. Comparison of risk and protective factors associated with smartphone addiction and Internet addiction. Journal of behavioral addictions. 2015; 4(4):308–14. https://doi.org/10.1556/2006.4.2015.043 PMID: 26690626

37. Chen YF. Social Phenomena of mobile phone use: An exploratory study in Taiwanese college students. Journal of Cyber Culture and InformationSociety2006. p. 219–44.
38. Javid M, Malik MA, Gujjar AA. Mobile Phone Culture and its Psychological Impacts on Students’ Learning at the University Level. Language in India. 2011; 11(2).
39. Lin YH, et al. Development and validation of the Smartphone Addiction Inventory (SPAI). PLoSOne. 2014; 9(6):88312.
40. República SdAEdPd. A mobilidade urbana no Brasil. site: http://www.ipea.gov.br 2011. p. 1–35.
41. Sánchez-Martínez M, Otero A. Factors associated with cell phone use in adolescents in the community of Madrid (Spain). Cyberpsychol Behav. 2009; 12(2):131–7. https://doi.org/10.1089/cpb.2008.0164 
42. Hair JF. Multivariate data analysis. 2009.
43. Faraggi D, Reiser B. Estimation of the area under the ROC curve. Statistics in medicine. 2002; 21 (20):3093–106. https://doi.org/10.1002/sim.1228 PMID: 12369084
44. Bowling A. Mode of questionnaire administration can have serious effects on data quality. J Public Health (Oxf). 2005; 27(3):281–91.
45. Kim K, Ryu E, Chon MY, Yeun EJ, Choi SY, Seo JS, et al. Internet addiction in Korean adolescents and its relation to depression and suicidal ideation: a questionnaire survey. Int J Nurs Stud. 2006; 43 (2):185–92. https://doi.org/10.1016/j.ijnurstu.2005.02.005 PMID: 16427966
46. Pavia L, Cavan D, Blasi M, Giordano C. Smartphone Addiction Inventory (SPAI): Psychometric properties and confirmatory factor analysis. Computers in Human Behavior. 2016; 63:170–8.
47. Puig DF. Prevención del Uso Problemático de Internet en smartphones. Barcelona: UOC Universitat Oberta de Catalunya; 2015.
48. Hwang K-h, Yoo R-s, Cho O-h. Smartphone overuse and upper extremity pain, anxiety, depression, and interpersonal relationships among college students. The Journal of the Korea Contents Association. 2012; 12(10):365–75.
49. Goodman A. Addiction: definition and implications. Br J Addict. 1990; 85(11):1403–8. PMID: 2285834
50. APA. Manual diagnóstico e Estatístico de Transtornos Mentais e de Comportamento da CID-10: descrições clínicas e diretrizes diagnósticas. Porto Alegre: Artmed; 1993.
51. APA. Manual diagnóstico e Estatístico de Transtornos Mentais: DSM-5: Artmed Editora; 2014.
52. Silveira DX, Vieira AC, Palomo V, Silveira ED. Criteria validity and reliability of the Brazilian version of a sexual addiction screening scale. Revista Brasileira de Psiquiatria. 2000; 22(1):4–10.
53. Cassin SE, von Ranson KM. Is binge eating experienced as an addiction? Appetite. 2007; 49(3):687–90. https://doi.org/10.1016/j.appet.2007.06.012 PMID: 17719677
54. Di Nicola M, Tedesci D, De Risio L, Pettoruso M, Martinniti G, Ruggeri F, et al. Co-occurrence of alcohol use disorder and behavioral addictions: relevance of impulsivity and craving. Drug and alcohol dependence. 2015; 148:118–25. https://doi.org/10.1016/j.drugalcdep.2014.12.028 PMID: 25630963
55. Targhetta R, Nalpa B, Perney P. Argentine tango: Another behavioral addiction? Journal of Behavioral Addictions. 2013; 2(3):179–86. https://doi.org/10.1556/JBA.2.2013.007 PMID: 25215199
56. Speranza M, Revah-Leyva A, Giquel L, Loas G, Venisse JL, Jeammet P, et al. An investigation of Goodman’s addictive disorder criteria in eating disorders. European Eating Disorders Review. 2012; 20 (3):182–9. https://doi.org/10.1002/erv.1140 PMID: 21834026
57. Meule A, Heckel D, Kübler A. Factor structure and item analysis of the Yale Food Addiction Scale in obese candidates for bariatric surgery. European Eating Disorders Review. 2012; 20(5):419–22. https://doi.org/10.1002/erv.2189 PMID: 22761046
58. Alavi SS, Ferdosi M, Jannatifard F, Esilami M, Alaghemandan H, Setare M. Behavioral addiction versus substance addiction: Correspondence of psychiatric and psychological views. International Journal of preventive medicine. 2012; 3(4).
59. Kafka MP. The development and evolution of the criteria for a newly proposed diagnosis for DSM-5: Hypersexuality disorder. Sexual Addiction & Compulsivity. 2013; 20(1–2):19–26. 
60. Hu L-t, Bentler PM. Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. Psychological methods. 1998; 3(4):424.
61. Kline RB. Principles and practice of structural equation modeling: Guilford publications; 2015.
62. Schermelleh-Engel K, Moosbrugger H, Müller H. Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. Methods of psychological research online. 2003; 8(2):23–74.
63. Lt Hu, 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.
64. Finney S, DiStefano C, Hancock G, Mueller R. A second course in structural equation modeling. Information Age Greenwich, CT; 2006.
65. BJ. The intraclass correlation coefficient as a measure of reliability. Psychol Rep. 1996; 19(1):3–11.
66. Smit F, Cuijpers P, Oostenbrink J, Batelaan N, de Graaf R, Beekman A. Costs of nine common mental disorders: implications for curative and preventive psychiatry. Journal of Mental Health Policy and Economics. 2006.
67. Smits N, Smit F, Cuijpers P, De Graaf R. Using decision theory to derive optimal cut-off scores of screening instruments: an illustration explicating costs and benefits of mental health screening. International journal of methods in psychiatric research. 2007; 16(4):219–29. https://doi.org/10.1002/mpr.230 PMID: 1818835
68. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. Radiology. 1982; 143(1):29–36. https://doi.org/10.1148/radiology.143.1.7063747 PMID: 7063747
69. Streiner DL, Cairney J. What's under the ROC? An introduction to receiver operating characteristics curves. The Canadian Journal of Psychiatry. 2007; 52(2):121–8. https://doi.org/10.1177/070674370705200210 PMID: 17375868
70. Capik C, Gozum S. Psychometric features of an assessment instrument with likert and dichotomous response formats. Public Health Nurs. 2015; 32(1):81–6. https://doi.org/10.1111/phin.12156 PMID: 25227501
71. Flaskerud JH. Cultural bias and Likert-type scales revisited. Issues Ment Health Nurs. 2012; 33(2):130–2. https://doi.org/10.3109/01612840.2011.600510 PMID: 22273348
72. Brown T. Confirmatory factor analysis for applied research. New York, NY: Guilford. Browne, MW, & Cudeck, R.(1993). Alternative ways of assessing model t. KA Bollen & JS Long. 2006.
73. Kline RB. Principles and practice of Structural Equation Modelling. London: The Guilford Press New York; 2011.
74. Kim SM, Huh HJ, Cho H, Kwon M, Choi JH, Ahn HJ, et al. The effect of depression, impulsivity, and resilience on smartphone addiction in university students. Journal of Korean Neuropsychiatric Association. 2014; 53(4):214–20.
75. Kline P. The handbook of psychological testing routledge. London; 1999.
76. Hakkaart-van Roijen L, Van Straten A, Al M, Rutten F, Donker M. Cost-utility of brief psychological treatment for depression and anxiety. The British Journal of Psychiatry. 2006; 188(4):323–9.
77. Valenstein M, Vijan S, Zeber JE, Boehm K, Buttar A. The cost–utility of screening for depression in primary care. Annals of Internal Medicine. 2001; 134(5):345–60. PMID: 11242495