

1 **Title**

2 Design and validation of a three-instrument toolkit for the assessment of competence
3 in ECG rhythm recognition.

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27 **Abstract**

28 *Background:* Rapid and accurate interpretation of cardiac arrhythmias by nurses has
29 been linked with safe practice and positive patient outcomes. Although training in
30 electrocardiogram (ECG) rhythm recognition is part of most undergraduate nursing
31 programmes, research continues to suggest that nurses and nursing students lack
32 competence in recognising cardiac rhythms. In order to promote patient safety,
33 nursing educators must develop valid and reliable assessment tools that allow the
34 rigorous assessment of this competence before nursing students are allowed to
35 practise without supervision.

36 *Aim:* To develop and psychometrically evaluate a toolkit to holistically assess
37 competence in ECG rhythm recognition.

38 *Methods:* Following a convenience sampling technique, 293 nursing students from a
39 nursing faculty in a Spanish university were recruited for the study. The following
40 three instruments were developed and psychometrically tested: a knowledge
41 assessment tool (ECG-KAT), a skills assessment tool (ECG-SAT) and a self-efficacy
42 assessment tool (ECG-SES). Reliability and validity (content, criterion and construct)
43 of these tools were meticulously examined.

44 *Results:* A high Cronbach's alpha coefficient demonstrated the excellent reliability of
45 the instruments (ECG-KAT=0.89; ECG-SAT=0.93; ECG-SES=0.98). An excellent
46 context validity index (S-CVI/Ave>0.94) and very good criterion validity were
47 evidenced for all the tools. Regarding construct validity, principal component analysis
48 revealed that all items comprising the instruments contributed to measure knowledge,
49 skills or self-efficacy in ECG rhythm recognition. Moreover, known-groups analysis

50 showed the tools' ability to detect expected differences in competence between
51 groups with different training experiences.

52 *Conclusion:* The three-instrument toolkit developed showed excellent psychometric
53 properties for measuring competence in ECG rhythm recognition.

54 **Keywords**

55 Competence assessment; nursing students; self-efficacy; knowledge; skills; cardiac
56 arrhythmias.

57 **Introduction**

58 Rapid and accurate interpretation of cardiac arrhythmias by nurses has been linked
59 with safe practice and positive patient outcomes.¹⁻⁴ Conversely, it has been
60 highlighted that errors in the recognition of life-threatening cardiac rhythms could
61 compromise patient outcomes.²⁻³ Consequently, regardless of their expertise, nurses
62 are expected to be competent in electrocardiogram (ECG) rhythm recognition.^{1-2,5-7}
63 Nonetheless, this is not always the case and research suggests that qualified nurses
64 often lack competence in ECG rhythm recognition.⁸⁻¹¹

65 In many countries, nursing education does not include a final licensing exam, which
66 means that nurses are allowed to practise without supervision immediately after
67 completing their undergraduate programmes.¹² Therefore, in order to promote patient
68 safety and positive patient outcomes,¹⁻⁴ most undergraduate programmes in nursing
69 include training in ECG rhythm recognition.¹³ In addition to this, our literature review
70 shows that numerous efforts to design and implement innovative training
71 interventions aiming to improve nursing students' acquisition and retention of
72 competence in ECG rhythm recognition have been made.¹⁴⁻¹⁸ However, the strategies
73 used to evaluate the educational effects of the innovative interventions implemented
74 in these studies were based on a traditional approach to competence assessment.¹⁹⁻²⁰

75 This means that the assessment of nursing students' competence mainly focused on
76 the partial evaluation of one or two of its domains (cognitive knowledge, performance
77 or confidence),¹⁹⁻²⁰ which implies that nursing students' overall competence in ECG
78 rhythm recognition remains unclear. Nursing educators are therefore challenged to
79 find more comprehensive, reliable and valid strategies for the rigorous assessment of
80 competence in ECG rhythm recognition.²¹⁻²⁴

81 Developing and implementing an assessment approach based on Bloom's and
82 Bandura's theoretical underpinnings could help to effectively address this
83 challenge.²⁵⁻²⁶ The adoption of Bloom's conception of competence as the individual's
84 capacity to integrate knowledge, skills and attitudes to make the most appropriate
85 decisions to achieve certain outcomes, may help improve the quality of
86 assessments.^{3,20,22,25} Furthermore, and following Bandura's theory, it is argued that the
87 acquisition of knowledge and skills does not entail competence unless individuals also
88 achieve a confident attitude in their ability to perform well.^{24,26-28} Therefore, being
89 competent in ECG rhythm recognition is understood here as having sound cognitive
90 knowledge of the theoretical underpinnings of ECG rhythm interpretation, having the
91 practical ability to recognise and name a cardiac rhythm recorded by an ECG, and
92 acquiring a certain level of self-efficacy towards one's own capability to effectively
93 perform the tasks involved in the process. Following our literature review, a lack of
94 valid and reliable instruments to assess all these domains of the competence was
95 found, so the aim of this study is to develop and psychometrically evaluate a toolkit to
96 holistically assess nursing students' competence in ECG rhythm recognition.

97 **Methods**

98 *Study design and participants*

99 The present study used an observational cross-sectional design. Students from one
100 Faculty of Nursing in Spain were recruited using a convenience sampling technique.
101 The inclusion criteria for participation were: 1) enrolled in a Nursing degree
102 programme during the 2015/2016 academic year, and 2) had not attended a training
103 session in ECG more than 3 months before the data collection. A total population of
104 320 Spanish-speaking individuals met these criteria and 293 voluntarily participated
105 in the study. Information about their age, gender and completed education was also
106 collected. In order to allow later known-groups comparisons, the 293 participants
107 were divided based on their last attended training in ECG rhythm recognition: 1)
108 never attended training (year-1 students), 2) attended training immediately before
109 completing the assessment (year-2 students), and 3) attended training between 1-3
110 months before the assessment (year-3 students).

111 ***Ethical considerations***

112 After the Institutional Ethics Committee granted ethical approval, a member of the
113 research team who was not part of the student Faculty contacted all individuals who
114 met the criteria to participate in the study. This intended to avoid influencing their
115 decision on whether or not to take part. A written document with information about
116 the research design, its aim and the participants' rights was handed out to all the
117 individuals who met the inclusion criteria. Volunteer participants were required to
118 sign an informed consent document before enrolment. All data collected were treated
119 in accordance with the European legislation on data protection.²⁹

120 ***Initial development of the instruments***

121 The toolkit for the holistic assessment of nursing students' competence in ECG
122 rhythm recognition was comprised of three instruments developed and tested in

123 Spanish: a knowledge assessment tool, a skills assessment tool and a self-efficacy
124 assessment tool.

125 A panel of 16 experts from 4 different institutions and a sample of 51 nursing students
126 participated in the initial pilot test of the instruments. All the experts were
127 experienced in either emergency, intensive or cardiac care and in teaching ECG
128 interpretation skills for nursing students. The same inclusion criteria, sampling
129 technique and ethical protocol used for the main sample were applied to the pilot
130 sample. However, the 51 participants in the pilot test did not participate in the main
131 validation study.

132 To assess content validity, the experts were asked to score each item as 1='not
133 relevant', 2='somewhat relevant', 3='quite relevant' or 4='highly relevant' for
134 measuring either knowledge, skills or self-efficacy in ECG rhythm recognition. Other
135 authors' recommendations were followed to calculate the items' content validity
136 index (I-CVI) for the initial version of the three assessment tools developed, and
137 items with a I-CVI<0.70 were immediately discarded.³⁰⁻³¹

138 To assess reliability and temporal stability, the pilot sample completed the
139 questionnaires for knowledge, skills and self-efficacy assessment twice with a 4-week
140 interval between them. While temporal stability of the tools was explored by
141 calculating the Pearson's correlation coefficients (r) for the test-retest results,
142 reliability was evaluated using the following three estimators for each individual
143 instrument: 1) Cronbach's coefficient alpha for the whole tool, 2) the corrected item-
144 total correlation (ITC) and 3) the estimated Cronbach's alpha of the tool if a particular
145 item was removed. Items were retained as part of the tools if: 1) item's corrected
146 ITC>0.3 and 2) the instrument's Cronbach's alpha coefficient did not increase after
147 removing that particular item.

148 To assess readability and understandability, the experts and the students were asked to
149 provide feedback on the wording of the items comprising the three tools and report
150 any difficulties when reading them.

151 Details of the development process and pilot study of each tool are presented below.

152 *The knowledge assessment tool*

153 For the evaluation of the 'knowledge' domain of the competence, a multiple-choice
154 questionnaire in ECG rhythm recognition (ECG-KAT) was created. The 20 questions
155 comprising the initial version of the ECG-KAT (i-ECG-KAT) only had one correct
156 answer out of four possible options [i.e. Question 4: what is the time equivalence in
157 seconds of one of the big squares on the ECG paper? Answer options: a) 0.04s; b)
158 0.4s; c) 0.02s; d) 0.2s]. These questions assessed cognitive knowledge in the topics
159 considered essential for the successful recognition of ECG rhythms: (1)
160 anatomophysiological principles of the cardiac function, (2) basic concepts of ECG
161 interpretation, (3) ECG's interpretation procedure, and (4) cardiac arrhythmias'
162 characteristics.¹⁷⁻¹⁸

163 The I-CVI of the 20 questions comprising the i-ECG-KAT ranged from 0.75-1 so all
164 of them were retained for its pilot study, after which this tool proved to be temporally
165 stable ($r=0.73$) and reliable (all items' ITC >0.3 ; Cronbach's $\alpha=0.85$, which would
166 not have significantly increased if any of the items were removed). Moreover,
167 experts' and students' feedback on the readability and understandability of the
168 instrument was positive and only minor changes to the wording of 4 questions were
169 applied.

170 *The skills assessment tool*

171 For the evaluation of the domain 'skills', a skill assessment tool in ECG rhythm
172 recognition (ECG-SAT) was created. The initial version of the ECG-SAT (i-ECG-

173 SAT) was comprised of 10 ECG rhythm-strips that the students would have to
174 individually interpret and name. In contrast to the skills tools found in the
175 literature,^{17,32} the i-ECG-SAT did not have an MCQ format. This means that the
176 participants were not given possible answers with each rhythm-strip, decreasing their
177 odds of getting the correct answer by chance and making the assessment more
178 realistic.

179 The 10 ECG rhythm-strips comprising the i-ECG-SAT were retained as their I-CVI
180 ranged from 0.87-1. After the pilot study, statistical analysis suggested that the i-
181 ECG-SAT was temporally stable ($r=0.79$) and reliable (all items' ITC >0.3 ;
182 Cronbach's $\alpha=0.89$, which would not have significantly increased if any of the
183 items were removed). Furthermore, experts and students provided only positive
184 comments on the tool's completion instructions.

185 *The self-efficacy assessment tool*

186 Self-efficacy is defined as people's beliefs in their capabilities to perform a particular
187 task and is considered to be the most important attitudinal component in the
188 development of a competence.^{26,33} Therefore, to measure the 'attitude' domain of this
189 competence, the self-efficacy scale in ECG rhythm recognition (ECG-SES) was
190 developed. Following Bandura's recommendations for the development of self-
191 efficacy questionnaires, the initial 15-item version of the ECG-SES (i-ECG-SES)
192 measured participants' confidence in terms of 'can do' using a 0-100 response-
193 scale.²⁶⁻²⁸ Furthermore, in order to avoid ceiling effects on participants' self-efficacy
194 scores, a certain level of difficulty was added to the statements included in each
195 item.²⁶

196 The I-CVI of the 15 items comprising the ECG-SES ranged from 0.75-1, meaning all
197 of them were retained for its pilot study, after which statistical analysis suggested that

198 the i-ECG-SES was temporally stable ($r=0.81$) and reliable (all items' ITC >0.4 ;
199 Cronbach's $\alpha=0.93$ that would not have significantly increased if any of the items
200 were removed). Additionally, experts' and students' feedback on the readability and
201 understandability of the tool was positive and only minor changes to the wording of 2
202 items were applied.

203 Lastly, the three instruments comprising the toolkit for the assessment of competence
204 in ECG rhythm recognition followed the structure of ordinal scales. The ECG-KAT
205 and ECG-SAT measured participants' knowledge and skills from 0-100. Each
206 question in the ECG-KAT and rhythm-strip in the ECG-SAT was given a
207 proportional and equal value. The ECG-SES measured participants' self-efficacy
208 from 0-100 using a Likert-type scale in which 0 meant 'completely sure I cannot do at
209 all' and 100 meant 'completely sure I can do'.

210 ***Data analysis of the instruments' final version***

211 Following other authors' recommendations, the already-piloted version of the three
212 instruments was psychometrically tested.^{27-28,30-31,34-35} IBM® SPSS® version 21 for
213 Mac® was used to perform the data analysis.

214 Readability and understandability. The readability and grade level of the ECG-KAT,
215 ECG-SAT, and ECG-SES was analysed using the Flesch-Kincaid tool in Microsoft
216 Word® 2011 for Mac®. To evaluate understandability, eight participants and three
217 independent non-native Spanish-speakers were asked to provide comments on any
218 difficulties found when reading the tools. Using non-native Spanish-speakers'
219 feedback about the understandability of the tools can contribute to further simplify
220 their readability.²⁷⁻²⁸ The completion time of the three instruments was also recorded.

221 *Reliability.* The methodology used to measure the final-version tools' reliability was
222 the same as the one already described in the 'initial development of the instruments'
223 section.

224 *Validity.* Content validity of the final version of the ECG-KAT, ECG-SAT and ECG-
225 SES was explored using the same method described in the section 'initial
226 development of the instruments'. In addition to this, the scales' average content
227 validity index (S-CVI/Ave) was calculated. In order to explore its criterion validity,
228 participants' results on the three instruments comprising the toolkit were compared to
229 other tools measuring similar constructs. Due to the lack of validated tools to which
230 the ECG-KAT and the ECG-SAT could be compared for criterion validity,
231 participants' results in both the ECG-KAT and ECG-SAT were correlated to their
232 results on the assessment tool developed and used by Varvaroussis' et al.¹⁷ Although
233 less specific than the ECG-KAT and ECG-SAT, this tool had been previously used
234 for the assessment of nursing students' knowledge-skills in cardiac arrhythmia
235 recognition. Similarly, in order to determine the ECG-SES' criterion validity,
236 participants' results in this tool were correlated to the New General Self-Efficacy
237 Scale (NGSES), which measures individuals' general self-efficacy.³⁶ For the
238 assessment of construct validity, the following two procedures were performed:

239 *Principal Component Analysis (PCA).* The Kaiser-Meyer-Olkin Measure of Sampling
240 Adequacy and the Bartlett's Test of Sphericity preceded the process of exploring the
241 factor structure of the ECG-KAT, ECG-SAT and ECG-SES. Then, an unlimited
242 factor analysis test with Varimax rotation was run. Decisions on the on the correct
243 structure of the three tools were made around the following criteria: (1) factors'
244 eigenvalues ≥ 1 , (2) existence of a clear graphic representation of the factor on the plot
245 of eigenvalues, and (3) items' factor loading value ≥ 0.5 .

246 *Known-groups analysis.* The total sample ($N=293$) was divided according to their last
247 attendance of a training session in ECG rhythm recognition (either never trained
248 ($n=98$), trained immediately before the assessment ($n=91$) or trained between 1-3
249 months before the assessment ($n=104$)). One-way analysis of variance (ANOVA) was
250 used to analyse known-groups differences. Moreover, to evaluate the differences
251 between groups' mean scores, Tukey's Honestly Significant Difference (HSD) post-
252 hoc tests were performed.

253 **Results**

254 *Description of the main sample*

255 Table 1 presents detailed demographic information of the main study sample ($N=293$)
256 and the known-groups. Female participants represented 80.5% of the total sample
257 ($n=236$), of which the mean age was 21.19 years ($SD=5.24$; range=17-54).
258 Furthermore, 76.8% ($n=225$) of participants had completed upper secondary
259 education before enrolling in the undergraduate nursing degree and approximately
260 40% ($n=114$) of participants had cooperated in the interpretation of an ECG rhythm-
261 strip. Lastly, one-way ANOVA results showed non-significant differences between
262 the known-groups for any of the demographic characteristics studied (see Table 1).

263 *Readability and understandability*

264 The reading level of the ECG-KAT, ECG-SAT and ECG-SES corresponds to 12th,
265 10th and 12th grade respectively. Neither the students nor the independent non-native
266 Spanish-speakers reported any difficulties understanding the content of the three
267 tools. Moreover, completion time register shows that participants took between 12-20
268 minutes for the ECG-KAT, 15 minutes for the ECG-SAT and 4-7 minutes for the
269 ECG-SES. The mean completion time of the overall toolkit was just under 40
270 minutes.

271 **Reliability**

272 The results of the reliability analysis for the three instruments are shown in Table 2
273 (ECG-KAT), Table 3 (ECG-SAT) and Table 4 (ECG-SES). The Cronbach's alpha
274 coefficient for these three tools was 0.89, 0.93 and 0.98 respectively. Furthermore,
275 ITC ranged from 0.38-0.66 for the ECG-KAT, from 0.38-0.88 for the ECG-SAT and
276 from 0.77-0.88 for the ECG-SES.

277 **Validity**

278 The I-CVI for the ECG-KAT, ECG-SAT and ECG-SES are presented in Table 2,
279 Table 3 and Table 4 respectively. The panel of 16 experts reviewing the three tools
280 considered that all items contributed to the operational definition of competence in
281 ECG rhythm recognition as a measurable construct. In support of this, the items' I-
282 CVI ranged from 0.75-1 and the tools' S-CVI/Ave were 0.94 (ECG-KAT), 0.97
283 (ECG-SAT) and 0.99 (ECG-SES). With regard to the criterion validity analysis, the
284 ECG-KAT, ECG-SAT and ECG-SES showed high correlation with the tools they
285 were compared to ($r=0.61$; $p<0.01$; $r=0.67$; $p<0.01$; $r=0.70$; $p<0.01$, respectively).
286 Results for the construct validity evaluation are as follows:

287 **PCA**

288 The results for the Kaiser-Meyer-Olkin measure of sampling adequacy were: 0.898
289 for the ECG-KAT, 0.914 for the ECG-SAT and 0.946 for the ECG-SES. Moreover,
290 the Barlett's Test of Sphericity was significant for all of them ($\chi^2=1224.87$; $p<0.01$;
291 $\chi^2=883.33$; $p<0.01$; $\chi^2=5905.77$; $p<0.01$), which means that it was appropriate to carry
292 out PCA for the three instruments.

293 In the case of the ECG-SAT' and ECG-SES' structure, only one factor evidenced a
294 clear graphic representation on the plot of eigenvalues and an eigenvalue ≥ 1 . This
295 factor accounted for 73% and 74.6% of the total variance found respectively. All the

296 items of both tools were retained as their component loading values varied from 0.44-
297 0.92 (ECG-SAT) and 0.80-0.90 (ECG-SES). On the contrary, the structure of the
298 ECG-KAT proved to have the following four factors, which accounted for 51.44% of
299 the total variance found: 1) anatomophysiological principles of the cardiac function,
300 2) fundamental concepts in ECG rhythm recognition, 3) interpretation procedure of
301 ECG rhythms, and 4) cardiac arrhythmias' characteristics (see Table 5).

302 *Known-groups analysis*

303 One-way ANOVA evidenced significant differences in the mean scores between the
304 three known-groups for the ECG-KAT ($F(2, 290) = 192.32; p < 0.01$), ECG-SAT ($F(2,$
305 $290) = 240.55; p < 0.01$) and ECG-SES ($F(2, 290) = 185.79; p < 0.01$). Finally, Table 6
306 shows the results for the known-groups analysis and Tukey's HSD post-hoc tests.

307 **Discussion**

308 Our literature review suggests there is a lack of valid and reliable tools that allow the
309 rigorous assessment of competence in ECG rhythm recognition amongst nursing
310 students. In light of this argument, the present study aimed to develop and
311 psychometrically evaluate a 3-instrument toolkit for the holistic assessment of
312 competence in ECG rhythm recognition.

313 As part of the psychometric assessment process of the three instruments, reliability
314 was carefully examined in order to determine whether they measured accurately. The
315 final version of the ECG-KAT, the ECG-SAT and the ECG-SES proved to have an
316 excellent internal consistency and a very good temporal stability, which evidences the
317 high reliability, repeatability and reproducibility of the three tools.³⁴⁻³⁵

318 Furthermore, content, criterion and construct validity of all the instruments were
319 meticulously tested in order to determine whether they actually measured what they
320 intended to. Content validity of the three tools was evidenced after a panel of 16

321 experts considered that the 20 items comprising the ECG-KAT, the 10 items
322 comprising the ECG-SAT and the 15 items comprising the ECG-SES were relevant
323 for operationalizing the respective assessment of knowledge, skills and confidence in
324 ECG rhythm recognition.³⁴⁻³⁵ In relation to criterion validity, all the tools designed in
325 this study correlated well with previously validated instruments measuring similar
326 concepts. This could be interpreted as an indicator of the ECG-KAT's, ECG-SAT's
327 and ECG-SES' ability to provide valid and reliable information about individuals'
328 knowledge, skills or confidence in recognising ECG rhythms.³⁴⁻³⁵ Additionally,
329 regarding construct validity, PCA showed that whereas the ECG-SAT and the ECG-
330 SES have a single-factor structure; the ECG-KAT has a 4-factor structure that
331 corresponds to the topics other authors have recommended to consider when teaching
332 how to recognise an ECG rhythm; these are: 1) anatomophysiological principles of
333 the cardiac function, 2) fundamental concepts in ECG rhythm recognition, 3)
334 interpretation procedure of ECG rhythms, and 4) cardiac arrhythmias'
335 characteristics.¹⁷⁻¹⁸ Moreover, corroborating the tools' construct validity, known-
336 group analysis revealed that the ECG-KAT, ECG-SAT and ECG-SES were able to
337 detect previously expected differences between individuals with different training
338 experiences.^{17,32}

339 Literature often suggests that nurses and nursing students' continue to lack
340 competence in ECG rhythm recognition,⁸⁻¹¹ which could interfere with the
341 achievement of positive patient outcomes.^{1,4,14} Consequently, nursing educators are
342 faced with the challenge of promoting safe practice by developing valid and reliable
343 assessments tools that can be used to rigorously assess nursing students' competence
344 before being allowed to work without supervision.^{6,37}

345 It has been argued that accepting the holistic definition of competence could help
346 nursing educators to develop more effective, valid and reliable assessment
347 tools.^{5,7,20,25} From this perspective, achieving a specific competence requires
348 individuals not only to acquire and retain the knowledge and the skills needed to
349 make the right decisions and correctly perform certain tasks, but also to adopt a
350 confident attitude toward their own ability to do so.^{25-28,33} Therefore, the development
351 of the ECG-KAT, ECG-SAT and ECG-SES as three independent instruments
352 comprising one comprehensive toolkit could contribute to the holistic and rigorous
353 assessment of nursing students' competence in ECG rhythm recognition as well as to
354 the understanding of their learning needs in this topic.

355 Although the evidence presented suggests that the toolkit developed for the
356 assessment of competence in ECG rhythm recognition is comprised of three reliable
357 and valid instruments, some limitations have been identified. Firstly, the sampling
358 method used in the study makes generalization of the results difficult. As the
359 participants were nursing students who met specific criteria, those willing to use the
360 ECG-KAT, ECG-SAT and ECG-SES to assess nurses' or other professionals'
361 competence should conduct a validation study before doing so. Secondly, due to
362 organizational constraints, the test-retest reliability of the tools was only assessed in
363 the piloted version of the 3-instrument toolkit. This makes it difficult to discard
364 between-subject differences as potential cause of the variability found in correlations.
365 To provide more clarity in this matter, future studies should apply test-retest measures
366 to the main sample and then calculate the intraclass correlation coefficient. Thirdly, in
367 regard to the validity of the ECG-SES it is important to highlight that due to the
368 subjective nature of the participants responses, the known-group analysis results could
369 have been influenced by social desirability response bias.³⁸ Finally, as the ECG-KAT,

370 ECG-SAT and ECG-SES were developed and tested in Spanish, those willing to use
371 them in different languages will have to conduct an appropriate translation and
372 validation process.

373 **Conclusions**

374 The toolkit developed for the assessment of competence in ECG rhythm recognition
375 has shown excellent psychometric properties following a rigorous testing process. The
376 ECG-KAT, ECG-SAT and ECG-SES comprise a valid, reliable and concise yet
377 comprehensive toolkit, which may allow educators to holistically assess nursing
378 students' competence in ECG rhythm recognition. Moreover, its easy and quick
379 applicability could foster the design, implementation and assessment of new
380 educational interventions, which aiming at improving competence in ECG rhythm
381 recognition amongst nursing students, may positively influence patients' outcomes. It
382 is suggested that further studies evaluate the psychometric properties of this toolkit
383 after being translated into other languages and validate its applicability on randomised
384 samples of nurses and nursing students with different professional and educational
385 backgrounds.

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390 **Conflict of interest**

391 Authors declare that there is not conflict of interest.

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Table 1.Demographic characteristics of the main sample ($N=293$) and the three known-groups.

Characteristic	Main Sample ($N=293$)	Not trained ($n=98$)	Trained immediately before assessment ($n=91$)	Trained 1-3 months before assessment ($n=104$)	Results and significance of the one-way ANOVA comparisons between known-groups
	$M \pm S.D.$	$M \pm S.D.$	$M \pm S.D.$	$M \pm S.D.$	
Age (years)	21.19 \pm 5.24	20.12 \pm 5.88	21.08 \pm 4.66	22.29 \pm 4.9	F(2,290) = 4.436, p = .053
	n (%)	n (%)	n (%)	n (%)	
Gender					
Female	236 (80.5)	78 (79.6)	73 (80.2)	85 (81.7)	F(2,290) = 0.077, p = .926
Male	57 (19.5)	20 (20.4)	18 (19.8)	19 (18.3)	
Education Level (completed)					
Upper Secondary Education	225 (76.8)	77 (78.6)	69 (75.8)	79 (76)	F(2,290) = 0.008, p = .992
Degree	68 (23.2)	21 (21.4)	22 (24.2)	25 (24)	
Cooperated in the interpretation of an ECG	114 (38.9)	34 (34.7)	33 (36.3)	47 (45.2)	F(2,290) = 1.363, p = .258

Table 2.
Psychometric statistics of item analysis for reliability and I-CVI of the ECG-KAT (*N*=293).

		Corrected ITC [†]	Cronbach's Alpha if item deleted	I-CVI [‡]
Question 1	Properties of the myocardial cells	.640	.882	1
Question 2	Cardiac conduction pathway	.447	.888	1
Question 3	Function of anatomical structures	.537	.885	1
Question 4	ECG paper grid	.376	.889	.94
Question 5	Defining characteristics of 'p waves'	.485	.887	1
Question 6	Defining characteristics of 'QRS complex'	.615	.883	1
Question 7	Defining characteristics of 't wave'	.512	.886	1
Question 8	Defining characteristics of 'PR interval'	.560	.884	1
Question 9	Defining characteristics of 'QT interval'	.563	.884	.94
Question 10	Clinical relevance of 'ST segment'	.478	.887	.94
Question 11	Duration of the 'QRS complex'	.571	.884	1
Question 12	Duration of the 'PR interval'	.385	.891	1
Question 13	Characteristics of first degree AV block	.621	.882	.94
Question 14	Characteristics of second degree AV block	.560	.884	.81
Question 15	Characteristics of third degree heart block	.511	.886	.81
Question 16	Characteristics of cardiac arrest arrhythmias	.376	.890	1
Question 17	Tachyarrhythmias	.520	.885	1
Question 18	Bradyarrhythmias	.659	.881	1
Question 19	Written interpretation of sinus rhythm	.455	.887	.75
Question 20	The six-stage method	.383	.891	.75

[†] ITC=Item-total correlation

[‡] I-CVI=Item Content Validity Index

Table 3.
Psychometric statistics of item analysis for reliability and I-CVI of the ECG-SAT ($N=293$).

		Corrected ITC [†]	Cronbach's Alpha if item deleted	I-CVI [‡]
1.	Sinus Bradicardia	.379	.934	.81
2.	Torsade de pointes	.881	.916	1
3.	Atrial Fibrillation	.523	.930	1
4.	Ventricular Fibrillation	.771	.922	1
5.	First degree AV-Block	.803	.920	1
6.	Junctional Rhythm	.874	.916	1
7.	Asystole	.744	.923	1
8.	Ventricular Tachycardia (broad)	.740	.923	1
9.	Sinus Rhythm with ST elevation	.798	.920	.94
10.	Second degree AV-Block (Mobitz II)	.773	.922	1

[†] ITC=Item-total correlation

[‡] I-CVI=Item Content Validity Index

Table 4.
Psychometric statistics of item analysis for reliability and I-CVI of the ECG-SES (N=293).

		Corrected ITC [†]	Cronbach's Alpha if item deleted	I-CVI [‡]
<i>When interpreting an ECG, I am confident I can always...</i>				
1.	Calculate the heart rate manually using a rhythm strip	.805	.974	1
2.	Determine whether the cardiac rhythm is regular or irregular	.772	.975	1
3.	Assess whether there is atrial electrical activity or not	.836	.974	1
4.	Assess whether there is ventricular electrical activity or not	.861	.973	1
5.	Identify whether the cardiac rhythm is originated in the atria or the ventricles	.877	.973	1
6.	Assess the relationship between the atrial and the ventricular activity	.882	.973	1
7.	Measure the interval that determines the atrioventricular activity	.856	.973	1
8.	Identify abnormalities in the duration of the intervals defining the atrioventricular activity	.823	.974	1
9.	Recognise a sinus rhythm	.821	.974	1
10.	Recognise and name any bradyarrhythmia regardless of its characteristics	.848	.974	1
11.	Recognise and name any tachyarrhythmia regardless of its characteristics	.846	.974	1
12.	Recognise and name any heart block regardless of its characteristics	.864	.973	1
13.	Recognise and name any arrhythmia that causes cardiac arrest regardless of its characteristics	.863	.973	1
14.	Recognise and name any life-threatening arrhythmia regardless of its characteristics	.876	.973	1
15.	Recognise and suspect possible signs of ischemia, injury or infarction	.796	.974	.94

[†] ITC=Item-total correlation

[‡] I-CVI=Item Content Validity Index

Table 5.
Factor loadings and total variance explained from the rotated factor structure of the ECG-KAT ($N=293$).

Item by Factor	Factor			
	1	2	3	4
1) Anatomophysiological principles of the cardiac function				
Properties of the myocardial cells	.70			
Cardiac conduction pathway	.54			
Function of anatomical structures	.51			
2) Fundamental concepts of ECG rhythm recognition				
ECG paper grid		.50		
Defining characteristics of 'p waves'		.61		
Defining characteristics of 'QRS complex'		.58		
Defining characteristics of 't wave'		.58		
Defining characteristics of 'PR interval'		.53		
Defining characteristics of 'QT interval'		.60		
Clinical relevance of 'ST segment'		.51		
3) Interpretation procedure of ECG rhythms				
The six-stage method			.51	
Duration of the 'QRS complex'			.56	
Duration of the 'PR interval'			.53	
4) Cardiac arrhythmias' characteristics				
Characteristics of first degree AV block				.72
Characteristics of second degree AV block				.71
Characteristics of third degree heart block				.69
Characteristics of cardiac arrest arrhythmias				.80
Tachyarrhythmias				.59
Bradyarrhythmias				.68
Written interpretation of sinus rhythm				.55
% of variance	5.47	7.50	5.22	33.25
Cumulative % of variance	5.47	12.97	18.19	51.44

Table 6.
Known groups analysis and Tukey's HSD post-hoc test for multiple comparisons.

Known-Groups	Not trained (n=98)	Trained immediately before testing (n=91)	Trained between 1- 3 months before testing (n=104)
Instrument	<i>M ± SD</i>	<i>M ± SD</i>	<i>M ± SD</i>
Known-group comparison	significance	significance	significance
ECG-KAT	31.43 ± 10.77	80.38 ± 21.32	53.08 ± 19.34
Not trained	-	.001	.001
Trained immediately before testing	.001	-	.001
Trained between 1-3 months before testing	.001	.001	-
ECG-SAT	13.98 ± 12.82	73.37 ± 23.67	33.63 ± 20.57
Not trained	-	.001	.001
Trained immediately before testing	.001	-	.001
Trained between 1-3 months before testing	.001	.001	-
ECG-SES	29.03 ± 14.68	75.15 ± 13.71	48.71 ± 22.17
Not trained	-	.001	.001
Trained immediately before testing	.001	-	.001
Trained between 1-3 months before testing	.001	.001	-