The development and psychometric evaluation of the Electronic Fetal Monitoring Knowledge Scale

Kleanthi Gourounti (✉ clairegourounti@yahoo.gr)

University of West Attica: Panepistemio Dytikes Attikes <https://orcid.org/0000-0002-2365-415X>

Antigoni Sarantaki

University of West Attica: Panepistemio Dytikes Attikes

Athina Diamanti

University of West Attica: Panepistemio Dytikes Attikes

Paraskevi Giaxi

University of West Attica: Panepistemio Dytikes Attikes

Katerina Lykeridou

University of West Attica: Panepistemio Dytikes Attikes

Research article

Keywords: knowledge, cardiotocography, electronic fetal monitoring

Posted Date: October 6th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-85431/v1>

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Abstract

Background. The aim of this study was to develop and assess the psychometric properties of the Electronic Fetal Monitoring Knowledge Scale (EFMKS), a self-report and short instrument measuring knowledge concerning Electronic Fetal Monitoring (EFM). Additionally, it was aimed to use the EFMKS for briefly assessing EFM knowledge in midwives and doctors working in labour ward.

Methods. The EFMKS was developed in a three-phase process by using an integrated mixed-methods approach that included literature reviews, professional focus groups, expert consultations and a psychometric survey evaluation. The psychometric evaluation was conducted by recruiting a sample of 128 professionals (midwives and doctors). Data were collected between April and July of 2016 in two public hospitals of Athens, Greece. Content validity, exploratory factor analysis, discriminant and construct validity, test-retest reliability and internal consistency were explored.

Results. The expert panel determined that the content validity was satisfactory. The final 10-item scale consisted of three factors explaining 73% of the total variance in the data. Discriminant validity was satisfactory. Internal consistency reliability ($\alpha = 0.89$) and test-retest reliability (0.85) were satisfactory. The majority of the midwives and the obstetricians had a good level of knowledge while approximately one third of them had a low level of knowledge in EFM. Midwives and doctors having a lower level of knowledge related to EFM, were more frequently professionals with less than five years of clinical experience in the labor ward and reported low confidence for cardiotocography (CTG) interpretation and inadequate preparation for CTG usage.

Conclusion. The EFMK demonstrated good content validity, an easily interpretable three-factor structure, high internal consistency, high test-retest reliability, and satisfactory discriminant and construct validity with sample characteristics. The EFMKS may be used for evaluating the EFM knowledge of health professionals and for identifying the areas of their knowledge gap. Based on study findings, an annual multi-professional CTG training is necessary for all intrapartum staff and in particular for the midwives and doctors with shorter clinical experience in the labor ward.

Background

Over the past 30 years, evidence has been produced and guidelines have been published demonstrating that electronic fetal monitoring (EFM) is of limited benefit for women considered “low risk” in obstetric terms compared to intermittent auscultation (IA) of the fetal heart rate (FHR) during labor [1, 2]. Despite the available evidence, EFM remains widespread in clinical practice in most European countries and certainly in Greece, in which almost all pregnant women receive EFM during labor. Barriers to implementing evidence-based guidelines may be the positive views of professionals towards EFM technology, the medicalization of childbirth, the poor staffing levels for offering one-to-one care and a poor knowledge level regarding the limitations of the EFM and mainly its low positive predictive value [3, 4, 5].

The continuous use of EFM during labor of low risk women and poor EFM interpretation may lead to an increased Caesarean section rate without a significant reduction in cerebral palsy or infant mortality [2, 6, 7]. Errors in the interpretation of cardiotocography (CTG) traces and failure to identify and manage pathological tracings are recognized causes of adverse obstetric outcomes [8, 9, 10, 11]. Additionally, cases of false interpretation and unsuitable management of cardiotocographic (CTG) traces may also lead to large financial costs [12]. Based on a 10-year report on maternity claims of the English National Health Service Litigation Authority (NHSLA) approximately 1 in 1000 births ends in litigation with the three most frequent causes of litigation relating to management of labor (including CTG interpretation), cerebral palsy and caesarean section [13]. The total amount of compensation for these maternity claims cost 3.1 billion English pounds. The Royal College of Obstetricians and Gynaecologists [14] stated on the English NHSLA report that the failure of the role of training and use of guidelines in claims needs to be assessed. Therefore, it can be concluded that CTG education is essential for reducing the incidence of hypoxic injuries during labor and for avoiding litigation.

Fetal surveillance education programs exist in Great Britain, the United States, Australia and New Zealand [15, 16, 17]. To ensure adherence to national and international guidelines, a Greek CTG education and assessment program was developed by the University of West Attica in 2015.

Several reports are available on the content of CTG training programs and many publications regarding the impact of CTG education programs on professionals' skills [11, 18, 19, 20]. However, we were unable to identify any published studies regarding the development of validated CTG tools measuring knowledge of midwives and obstetricians regarding the EFM. A lack of validated assessment methods has been indicated by Pehrson, Sorensen and Amer-Wahlin, [19] too.

The aim of this study was to develop and validate a self-report and short instrument measuring knowledge concerning electronic fetal monitoring. This instrument has the potential to provide a validated and feasible method of briefly assessing EFM knowledge in general. Therefore, it was additionally aimed to use the EFMKS for briefly assessing EFM knowledge in midwives and doctors working in labour ward.

Methods

Study design

This study was designed for scale development. The scale was prepared in the Greek language, and its development included three main phases: item generation, item reduction, initial validity testing (content validity testing), construct validity testing (exploratory factor analysis (EFA), reliability testing and criterion-related validity).

Instrument development

Phase I: Item generation

The goal of phase I was to generate the items for the instrument from two main sources: a) an extensive literature review of the international guidelines on EFM [17, 21, 22, 23, 24] and of reports on the content of EFM training programs [15, 17, 25], followed by a review of the Delphi survey data from a previous study [12]; and b) a focus group including six experienced midwives and six experienced obstetricians. Experience was defined as having teaching and clinical experience on EFM for more than five years. Finally, a 25-item pool of items regarding fetal physiology, interpretation, classification and management was established.

Phase II: Content validity testing and item reduction

Once the item pool was developed from phase I, the goals of the phase II were to assess the content validity and reduce the number of questions for further scale development by assembling a panel of four experts on EFM. These experts included one chief obstetrician, one chief midwife, one professor of Midwifery and one professor of Obstetrics and Fetal Medicine. Initially, the expert panel rephrased and revised the items in the item pool to make it more concise and comprehensible. Items with semantic similarity were deleted to avoid redundancy. The items that were kept were the most clear and concise. As a result, nine items were deleted and a 16-item instrument resulted (see Appendix 1, supplementary material).

To evaluate the content validity of the items, expert panel was also used. Content validity measures how well items correspond or reflect a specific domain and are measured usually using quantitative and qualitative techniques (e.g. focus groups, interviews) [26, 27]. Multiple methods are used for testing content validity, and the content validity index (CVI) is the most widely reported approach for assessing content validity in instrument development and can be computed using the Item-CVI [27]. This study used one method that involved empirical techniques to calculate the index of item-content validity (I-CVI). The CVI was calculated using a four-point ordinal scale ranging from 1 (not relevant) to 4 (very relevant). The CVI for an item is the proportion of experts who rate it as 3 or 4 divided by the number of experts [28]. A 0.75 CVI value was used as the acceptable minimal CVI value [29]. The experts returned their rating scales, and four more items with CVI ranging from 0.50 to 0.69 were deleted. The four items that were deleted because of a low I-CVI were the items Q22 ("differences between CTG and STAN"), Q23 ("Operation CTG equipment and application of transducers"), Q24 ("application of a fetal scalp electrode"), Q25 ("advantages and disadvantages of internal and external monitoring"). These items were considered irrelevant mostly because of their low applicability in the Greek hospital settings in which it is unusual to use internal monitoring and STAN analysis. This resulted in a revised instrument with 12 items and the total CVI score was 0.85.

Phase III: Reliability and validity testing

The goals of phase III were to test the performance of the 12 items in a sample of midwives and medical doctors by testing the reliability, exploring the factor structure of the instrument comprising the scale, testing the discriminant and construct validity and determine the scale's test-retest reliability and stability in a repeated administration. For the test-retest reliability assessment a retest interval of 2–14 days is usual [30]. However, the researcher needs to consider factors such as the effects of time on knowledge to

make an appropriate decision about the time interval between the tests [31]. Therefore, a retest interval of one week was chosen considering the scope of this research (e.g. a shorter interval might lead to memory effects). Reliability was assessed by computing an internal consistency coefficient. Internal consistency was determined: (a) by using Cronbach's alpha and (b) by examining the change in Cronbach's α coefficient if an item was deleted from the scale. A minimum Cronbach's α value of 0.70 for group comparisons is acceptable [32, 33, 34]. In addition, poor items are defined as those that, when deleted, increase the coefficient α by 0.1 or more. To evaluate the items of the instrument further, item analysis was performed by evaluating the item-total correlations. Items with item-total correlations below 0.30 or above 0.80 should be revised or deleted [35, 36].

Cronbach's alpha coefficient for the total scale with 12 items was 0.86. Two items proved problematic in terms of their item-total correlation's namely item Q21: "evaluate the pattern of contractions" and item Q16: "interpret a fetal scalp-blood sample". For the rest of the items the values for the corrected item total correlations test ranged from 0.38 to 0.71, while for these two items it was 0.21 and 0.14, respectively. The deletion of these two items improved Cronbach's alpha value. Therefore, items 9 and 4 were excluded from further interpretation in the reliability assessment and the factor analysis. This resulted in a revised instrument with 10 items.

Sample

The study was conducted in two public maternity clinics in Greece with an annual birth rate of approximately 3500 births. Data were collected between April and July of 2016. During the recruitment period, all eligible professionals (midwives and doctors) who worked in the labor ward during at least the past 12 months ($N = 156$) were invited to participate in the study, and a total of 128 professionals agreed to participate and completed the questionnaires (response rate 82%). Non-participation was mainly due to lack of time of the professionals. The total of 128 professionals, including midwives (32 midwives and 32 student midwives undertaking their practical training) and doctors (32 obstetricians and 32 resident obstetricians), were recruited for the survey through random sampling.

A total of 128 professionals and students were included in the analyses concerning the factor structure, the internal consistency testing, the discriminant and construct validity testing and the test-retest reliability assessment. The total sample of 128 professional midwives and obstetricians was adequate for exploratory factor analysis (10 participants per item), as recommended by Nunnally [37] and by Kass and Tinsley [38]. The test-retest reliability of the questionnaire was calculated for 60 (who agreed to complete the retest of the EFMKS) out of 128 professionals who agreed to repeat EFMKS one week after the first administration (68 participants did not agree to complete retest the EFMKS due to lack of time).

Instruments

Demographic data

Data on gender, age, employment status (professional or student/resident), and duration of clinical experience were collected using a specially designed form. Two dichotomous questions asked

participants: a) their confidence about interpreting CTG traces and b) their feeling of having adequate training for CTG usage.

Electronic Fetal Monitoring Knowledge Scale (EFMKS)

The version of the EFMKS that emerged from phases I, II, and III of the instrument development process consisted of items designed to measure the level of knowledge regarding the electronic fetal monitoring (see Appendix 2, supplementary material). Every question was a multiple choice question, asking to select one or more than one answer, and for every correct answer a point was allocated. Professionals with higher scores were classified as having better level of knowledge. The cut-off was defined by the scale midpoint rather than the sample median because external criteria for 'good' and 'poor' knowledge were not available. Permission for the use of the entire EFMKS can be obtained from the corresponding author at the request of professionals or organizations who wish to use it.

Data Analysis

Statistical analysis was performed using SPSS version 24.0 [39]. Descriptive statistics, such as means, standard deviations, and frequencies, were used to present the demographic characteristics of the participants and to describe the scale.

Factor structure of the EFMKS

Exploratory factor analysis (EFA) was used to assess the construct validity of the instrument and explore the factor structure of the EFMKS. The EFA was conducted by using Principal Components Analysis (PCA) with Varimax rotation. Varimax was used for attempting to maximize the dispersion of loadings within factors and for ensuring that the factors will be remained uncorrelated [40]. The appropriateness of the factor model was evaluated based on three criteria. First, the magnitude of Kaiser–Meyer–Olkin (KMO) test was computed to measure sampling adequacy, which should be greater than 0.70 for a satisfactory factor analysis to proceed [41]. Second, communalities should be above 0.35 [42, 43]. Third, the Bartlett Sphericity test was also applied to the data and should be statistically significant. The statistical criteria guiding the determination of the number of the factors to retain were eigenvalues greater than 1.0 and the visual inspection of Catell's scree test, looking for the break point where the curve flattened out [44, 45]. The next step involved interpreting the rotated solution by identifying which items loaded substantially on each retained factor.

Discriminant and construct validity

Discriminant validity was assessed by examining the intercorrelations between the factors of the EFMKS. Construct validity was established by assessing the ability of the EFMKS to distinguish between subgroups of each profession (midwives and obstetricians) known to differ in knowledge and clinical competences (subgroup of student midwives and resident obstetricians vs professional midwives and obstetricians respectively). Pearson correlation coefficients were used to measure the linear associations among the EFMKS factors. Any factor that correlated by > 0.7 was considered to overlap conceptually. Additionally, the associations among the EFMKS score and the characteristics of the sample were

assessed using the Pearson correlation coefficients, t-test, one-way ANOVA. The level for statistical significance was set at $p < 0.05$.

Ethics

The study protocol was reviewed and approved by the Elena Benizelou-Alexandra Hospital Research and Ethics Committee (No 12/14-10-2015). All participants in this study were informed about the scope, the purpose of the study, expected outcomes, and their right to refuse. Eligible participants were also assured about the confidentiality and anonymity of their responses. Written consent was taken from all the participants before filling in the questionnaires.

Results

Sample characteristics

The majority of the professionals (71.9%, $n = 46$) had clinical experience in the labor ward for no more than five years (53.2% of midwives, $n = 17$, and 90% of the obstetricians, $n = 29$). The midwifery students ($n = 32$) participated in the last training year and the resident obstetricians had a mean duration of clinical experience of 2.5 years. The mean age of the participants was 40.4 years (38.3 years for the midwives and 42.7 years for the obstetricians). The majority of the professionals (67.2%, $n = 43$) reported that they felt confident about interpreting CTG traces (59.4% of midwives, $n = 19$, and 75% of the obstetricians, $n = 24$). However, approximately only half of the professionals (54.7%, $n = 35$) reported that they felt that their training adequately prepared them for CTG usage (56.3% of midwives, $n = 18$, and 53.1% of the obstetricians, $n = 17$).

Questionnaire refinement results

Reliability assessment: Internal Consistency and Test-Retest Reliability.

The Cronbach's alpha coefficient of internal consistency for the 10-item scale was 0.89, the corrected item total correlations ranged from 0.45 to 0.85, indicating sufficient inter-relationships in the data to conduct an exploratory factor analysis and none of the items improved the scale's Cronbach's alpha estimate if deleted. The test-retest reliability of the scale for the two administrations was correlated at 0.85 ($p < 0.01$).

Factor structure of the EFMKS

The Kaiser-Meyer-Olkin value was 0.824 and Bartlett's test of sphericity reached statistical significance ($\chi^2 = 747$, $df = 45$, $p < 0.001$). These findings indicated that the data were suitable for a factor analysis [40]. All initial communalities were ≥ 0.35 , and all of them ranged from 0.629 to 0.885 (Table 1). The exploratory factor analysis suggested three factors with eigenvalues greater than 1, accounting for 72.99% of the variance (Table 1). All factors with an eigenvalue more than >1 showed consistency with the visual scree plot.

Factor interpretation and naming

Inspection of the derived factors revealed meaningful groupings of the items. Factor 1 had four strongly loading items: on Q1 “range and determinants of fetal heart rate (FHR) baseline”, on Q2 “range and determinants of fetal heart rate variability”, on Q3 “key characteristics (accelerations) of a reactive NST”, and on Q4 “identification and attribution of variable decelerations” (Table 1). Substantively, the considered interpretation of this factor seems best focused on the midwives’ and doctors’ knowledge on key elements of CTG and on identification of normal CTG patterns. The factor was therefore named as “key elements of CTG and normal CTG patterns”.

Factor 2 had three strongly loading items: on Q5 “identification and attribution of late decelerations”, on Q6 “management of bradycardia during labor” and on Q10 “classification of CTG traces from compensatory to abnormal”. Two items (5, 6) also loaded on Factor 1, but they were assigned to the factor with the highest loading. For Factor 2, the underlying concept seemed to be on abnormal CTG and on CTG during labor. The factor was therefore designated as “suspicious and abnormal CTG patterns”.

Factor 3 had three strongly loading items: on Q8 “risk of neurological defect and acidosis”, on Q7 “association between Apgar score, accelerations during labor and acidosis” and on Q9 “association between progressive hypoxia and CTG traces”. The factor was therefore designated as “hypoxia, acidosis and CTG traces”.

Discriminant and construct validity

To determine whether EFMKS is sensitive to differences in clinical experience of participants, a t-test was used. The significant and positive associations between the mean score of EFMKS scale and the professional experience of participants suggested that EFMKS achieved discriminant and construct validity. The sensitivity analysis detected a significant difference in mean test score between obstetricians and residents ($t = 5.717$, $p = 0.020$) and between midwives and student midwives ($t = 4.553$, $p = 0.033$), indicating acceptable test construct abilities.

The strength of associations between the derived scales of the EFMKS scale was tested. Positive, medium and statistically significant associations were obtained among the factors: that is, the factor “key elements of CTG and normal CTG patterns” with the factor “suspicious and abnormal CTG patterns” ($r = 0.695$, $p < 0.001$) and with factor “hypoxia, acidosis and CTG traces” ($r = 0.689$, $p < 0.001$), and the factor “suspicious and abnormal CTG patterns” with factor “hypoxia, acidosis and CTG traces” ($r = 0.654$, $p < 0.001$).

Table 1
Factor structure of the Electronic Fetal Monitoring Knowledge Scale (EFMKS)

Item/ Item statement	Loading	Communality
Factor1 (Eigenvalue = 3.32, variance explained = 33.27%, $\alpha = 0.85$)		
3/ Key characteristics of a reactive NST	0.812	0.771
4/ Definition and attribution of variable decelerations	0.805	0.669
1/ Range and determinants of FHR baseline	0.778	0.793
4/ Range and determinants of FHR variability	0.751	0.832
Factor 2 (Eigenvalue = 2.41, variance explained = 24.12%, cumulative variance explained = 57.39%, $\alpha = 0.82$)		
10/ Classification of CTG traces from compensatory to abnormal	0.860	0.885
6/ Definition and management of severe bradycardia	0.725	0.635
5/ Definition and attribution of late decelerations	0.712	0.680
Factor 3 (Eigenvalue = 1.56, variance explained = 15.6%, cumulative variance explained = 72.99%, $\alpha = 0.80$)		
7/ Progressive hypoxia and CTG traces	0.785	0.637
8/ Identification of risk for neurological defect and ph	0.749	0.629
5/Apgar score, accelerations and risk of acidosis	0.745	0.769
NST: Non stress test, FHR: Fetal Heart Rate, CTG: Cardiotocography		

Descriptive findings of the EFMK scale

The score of the 10-item EFMK scale ranged from 0 (indicating no correct answers) to 10 (indicating all correct answers), and professionals with scores of greater than five (the mid-point) were classified as having good knowledge about EFM, and those with scores of four and below were classified as having poor knowledge. The rationale for using a cut off of 5 for the knowledge scale was pragmatic as 5 represented the midpoint and the median of the scale. The terms good and poor imply an absolute standard against which knowledge is judged. Such a standard should and is planned to be developed in the future. For the present, however, the only standard is a relative one, that is, knowledge is judged as poor in the context of the scale's median.

The mean score for the total EFMKS was 6.84 (SD = 3.11), for the subscale measuring the "key elements of CTG and normal CTG patterns" with range from 0 to 4, the mean score was 2.31 (SD=1.7); for the "suspicious and abnormal CTG patterns" subscale (range from 0 to 3), the mean score was 2.21 (SD=0.96), and for the "hypoxia, acidosis and CTG traces" subscale (range from 0 to 3), the mean was 2.31 (SD= 0.85). Taking into consideration the midpoint of the scale (5), the mean score of our sample indicated a good level of knowledge. More specifically, 73.4% of the total sample (71.9% of the professional midwives and 75% of the professional obstetricians) had a good level of knowledge (score of more than 5 points).

Correlations between professionals' characteristics and EFMK Scale score

The association between participants' level of knowledge and their characteristics was explored (Table 2). No statistically significant difference was observed between group of midwives and group of obstetricians in terms of total knowledge score ($p=0.768$). Professionals with longer experience in the labor ward had statistically higher mean scores in subscales measuring "suspicious and abnormal CTG patterns" and "hypoxia, acidosis and CTG traces" than professionals with shorter clinical experience. No statistically significant relationship was observed between knowledge level and professionals' age. Interestingly, the professionals reporting being confident and adequately prepared for CTG usage had significantly higher mean knowledge scores.

Table 2
Associations between Electronic Fetal Monitoring Knowledge Scale (EFMKS) and characteristics of the professionals involved in the study.

EFKM Scale and Subscales (means)				
Professionals' characteristics	Total EFKM scale	Subscale: 'Key elements of CTG and normal CTG patterns' (means)	Subscale: "suspicious and abnormal CTG patterns" (means)	Subscale: "hypoxia, acidosis and CTG traces" (means)
Professional Midwives	6.46	2.62	1.68	2.15
Professional Obstetricians	7.21	2.75	2.00	2.46
p value	0.768	0.498	0.315	0.246
Years of labor ward experience < 5	6.43	2.01	2.08	2.01
Years of labor ward experience ≥ 5	7.88	2.50	2.88	2.72
p value	0.010	0.336	0.003	0.045
Professionals reporting not being confident for CTG interpretation	4.04	1.61	0.76	1.66
Professionals reporting confident for CTG interpretation	8.20	3.20	2.37	2.62
p value	0.010	0.004	0.002	0.038
Professionals not feeling adequately trained for CTG usage	4.86	1.93	1.03	1.89
Professionals feeling adequately trained for CTG usage	8.48	3.31	2.51	2.65
p value	0.001	0.006	0.005	0.048
CTG: Cardiotocography				

Discussion

It has been well-documented that when electronic fetal monitoring is performed by professionals without having the appropriate knowledge and skills, the possible consequences are an increased rate of Cesarean sections and increased litigation regarding avoidable intrapartum asphyxia [46, 47]. However, an exhaustive search of the literature has failed to identify previous studies on developing or using a validated instrument for measuring midwives' and obstetricians' knowledge and skills related to electronic fetal monitoring.

The purpose of this study was to develop and validate a self-repost measure of knowledge, skills and clinical decision-making related to electronic fetal monitoring. Through an iterative, rigorous instrument development process, the EFMK scale was developed and tested. The EFMKS was developed by using an integrated mixed-methods approach that included literature reviews, international guidelines, professional focus groups, expert consultations and a psychometric survey evaluation. The EFMK scale demonstrated good content validity, an easily interpretable three-factor structure, high internal consistency, high test-retest reliability, and satisfactory discriminant validity with sample characteristics.

Content validity refers to the extent to which a specific set of items reflects a content domain [48] and the most frequently used method for assessing content validity is the expert panel method by using 3 to 10 experts [35]. A CVI value above 0.80 indicates adequate content validity [35]. However, in this study a 0.75 CVI value was used, as it is the acceptable minimal CVI value [29] for not deleting some useful items based on strict statistical criteria. After the item pool was generated (through literature review, focus group discussion), the initial version of the scale was developed through a panel of four experts, and the overall value of the CVI was 0.85, suggesting that this scale has good content validity.

Exploratory factor analysis is a useful analytic method, primarily a data-driven approach, which is generally used when no sufficient theoretical or empirical basis exists to make strong assumptions about how many constructs or factors underlie a set of items [48]. The results of the exploratory factor analysis suggested that a discriminative capacity existed among the items and that a three-factor solution was the most appropriate. The underlying concepts of the three-factor structure were interpreted by the authors and labelled "key elements of CTG and normal CTG patterns", "suspicious and abnormal CTG patterns" and "hypoxia, acidosis and CTG traces" in accordance with the essence of the items and these factors. This finding indicated that the knowledge and competence skills related to electronic fetal monitoring were multidimensional, variable and related not only with CTG trace interpretation and classification but also with fetal physiology and acid-base balance in relation to cardiotocography.

All the items loaded satisfactorily in factors with loadings ranging from 0.71 to 0.86 and had item-total correlation values higher than 0.30 but without exceeding 0.80 indicating that all the items measured a

relevant but not the same underlying construct. The three-factor solution of the EFMK 10-item scale cumulatively accounted for the 72.9% of variance. This result indicated that the developed EFMK scale explained a high proportion of the tested knowledge variables. An initial data analysis should use EFA to identify potential factors. Confirmatory factor analysis was not conducted because it is a technique that requires an a priori specification of the construct relationship between the potential factors. Therefore, the factorial structure of the EFMKS must be verified in another sample of professionals through a confirmatory factor analysis.

In this study, the Cronbach's α coefficient and test-retest reliability of the EFMKS were 0.89 and 0.85, respectively, indicating good reliability. These data suggested that the EFMKS was a relatively homogeneous scale and that the scale consistently measured the same construct.

The sensitivity analysis detected a significant difference in mean EFMK score between obstetricians and residents and between midwives and students midwives. These results were similar to the findings of the study by Thellesen et al. [49] and indicated that the EFMKS displayed satisfactory construct validity. In addition, the associations between the derived scales of the EFMK scale were positive, significant and medium in size. This finding designated that the three factors were not overlapping and were indeed measuring three separate although related dimensions of the EFM knowledge. Convergent validity (e.g. the extent to which a test correlates with other variables with which it theoretically should correlate) could not be assessed because, according to the authors' knowledge, no other validated instrument measuring EFM knowledge was available.

Taking into consideration the midpoint of the scale (5 points), the mean score of our total sample indicated a good level of knowledge on EFM. More specifically, 71.9% of the professional midwives and 75% of the professional obstetricians had a good level of knowledge (score of more than 5 points). Despite differences in basic training and philosophies, an independent t-test demonstrated no difference between midwives and obstetricians knowledge related to EFM. This finding was similar to the findings of previous studies [49, 50]. However, it was noteworthy that approximately 30% of the professional midwives and 25% of the obstetricians, both of the professional groups with clinical experience in the labor ward, had a low level of knowledge in EFM. These results support the findings of previous studies, which suggest that knowledge regarding EFM remains intact only for some months after a training program [51] and that an annual update course in fetal monitoring is recommended and necessary [11, 52, 53]. It is noteworthy that the fourth CESDI [54] report recommends that CTG training needs to be repeated every six months. Besides the repeatability of the CTG training, a study by Ayres-de-Campos et al. [55] suggests that CTG interpretive skills are also positively affected by increasing the knowledge related to fetal physiology.

The low score of knowledge on the EFMK scale was significantly more frequent among the midwives and doctors with less than five years of clinical experience in the labor ward. These findings are similar to the findings of a previous study in which it was concluded the group of junior medical doctors most frequently involved in cases of suboptimal intrapartum care [56]. In addition, the professionals reporting

lower confidence and feeling not adequately prepared for CTG usage had significantly lower mean knowledge scores. This corresponds with previous studies conducted by [57, 58, 4]. Therefore, it was interesting to note that midwives and doctors working in the labor ward and having a low level of knowledge related to EFM, reported low confidence for CTG interpretation and inadequate preparation for CTG usage. Therefore, an annual multi-professional CTG education and training should be mandatory for all intrapartum care staff. The CTG training programs should lay a foundation in fetal physiology and the normal fetal response to labor as this grounding is important for the proper CTG interpretation and management [51]. Sinclair [59] argues that competence increases confidence, which in turn promotes autonomy.

Results of this study need to be interpreted within the light of some limitations. First, convenience sampling was used. Additionally, the sample of professionals was drawn only from two public hospitals from the capital of Greece. Thus, the results of this study may have introduced a selection bias and produced a non-representative sample of midwives and obstetricians in Greece so that the results are not likely to be generalizable. Therefore, it is essential to explore the psychometric properties and assess this scale among professionals from different settings (e.g., private hospitals) and different geographic regions. Additionally, the results of this study concerning the percentage of high and low knowledge score were based on a cut off score which represented the midpoint and the median of the scale. Therefore, it is important to stratify in the future the cut-off score value of this scale by using finer adjustments (e.g. applying the scale on a standardized population assumed of having high level of knowledge and on a standardized population assumed of having very low level of knowledge). Finally, the EFMK scale although it is a knowledge scale (in which respondents' performance on one item may be unrelated to their performance on another item) was validated only through classical statistical analyses (e.g. EFA, Cronbach alpha) as a multidimensional scale and was not validated through analyses of item response theory which has measurement advantages (e.g. relates the probability of a correct response to a specific knowledge items to the respondent's overall amount of knowledge that scale is measuring) over classical methods of measurement [30].

Conclusion

In conclusion, the EFMKS was found to have satisfactory psychometric properties with a meaningful three-factor structure, good internal reliability and good discriminant and construct validity. Based on the study findings, the EFMKS may be used for evaluating, in a multidimensional way, the EFM knowledge of midwives and of obstetricians and for identifying the areas of knowledge gap (e.g., acid-base balance) among professionals who use it. Taking into consideration the study findings it can be concluded that an annual multi-professional CTG training is necessary for all intrapartum staff and in particular for the midwives and doctors with shorter clinical experience in the labor ward. It is hoped that through training and consequently the improvement of knowledge and competences regarding EFM the nationally increasing number of Caesarean sections may be reduced. Future research should aim to investigate the factorial structure of the EFMKS in samples from other settings. In addition, future research should

investigate the factorial structure of the EFMKS must be verified in another sample of professionals through a confirmatory factor analysis.

Abbreviations

CTG: cardiotocography

CVI: content validity index

EFM: Electronic Fetal Monitoring

EFMKS: Electronic Fetal Monitoring Knowledge Scale

EFA: exploratory factor analysis

FHR: fetal heart rate

KMO: Kaiser–Meyer–Olkin test

NST: Non stress test

PCA: Principal Components Analysis

Declarations

Acknowledgments

The authors would like to thank data collectors and supervisors for their invaluable effort to make this study real. The author's deep gratitude also goes to study subjects who were volunteered and took their time to give all the relevant information for the study

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Funding

The authors declare that they have no funding

Author information

Affiliations

Department of Midwifery, University of West Attica, Athens, Greece,

Ag. Spyridonos 28, Aigaleo, 12243, Athens, Greece

Kleanthi Gourounti, Antigoni Sarantaki, Athina Diamanti, Paraskevi Giaxi, Katerina Lykeridou

KG, RM, MSc, MMedSc, Phd, Associate Professor in Midwifery, University of West Attica, President of the Hellenic Society of Fetal Monitoring and Safe Birth,

AS, RM, MSc, Phd, Assistant Professor in Midwifery, University of West Attica,

AD, RN, RM, MSc, Phd, Research Fellow in Midwifery, University of West Attica,

PG, RM, MSc, Phdc, Research Fellow in Midwifery, University of West Attica,

KL, RM, RN, MSc, Phd, Professor in Midwifery, University of West Attica

Authors' Contributions

KG initiated the research, wrote the research proposal, conducted the field work, supervised data entry, analyzed the data, and wrote the manuscript. AS, AD, VG, and KL participated in refining the research proposal, contributing the discussion and interpretation of data. All the authors have read and approved the final manuscript.

Corresponding author

Correspondence to: Kleanthi Gourounti

Ethics approval and consent to participate

This study was reviewed and approved by the Elena Benizelou-Alexandra Hospital Research and Ethics Committee (No 12/14-10-2015).

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

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