

# Impact of Educational and Visual Sign Interventions on Noise Reduction in Neonatal Intensive Care Units (NICUs)

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## Research article

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# Abstract

**Background** High levels of sound have several negative impacts such as noise-induced hearing loss and delayed growth and development on newborn in NICUs. The American Academy of Pediatrics recommends that NICU sound levels remain below 45 dBA. The aim of this research is to determine the effect of educational and visual sign interventions on noise reduction in Neonatal Intensive Care Units.

**Methods** This Quasi-experimental study (before-after study) was conducted in the NICU of Vali-e-Asr Hospital, Birjand in 2016. A total of 21 participants including NICU doctors and hospital staff could enter the NICU. The sound levels in the NICU were measured by a calibrated digital sound-level meter and placed at a height of 1.5 meters at various stations and three different working shifts. Subsequently, the post-training and visual signs (flags and posters) were utilized at the NICU.

**Results** There was a significant difference in the means of the sound levels between stages 2 and 3 of the study ( $P=0.009$ ) as well as a significant decrease in the level of sound between stages 2 and 3. The means of the minimum sound level in the morning and night shifts in the three different study periods indicated a significant decline ( $P<0.05$ ), while in the afternoon shifts the minimum sound levels showed a significant increase which was also significant before and after the intervention ( $P=0.046$ ). The maximum sound level dropped significantly ( $P=0.045$ ) in the night shift compared to the three different study periods, as well as in the pre- and post-intervention phases ( $P=0.04$ ).

**Conclusions** Noise in our NICU was more than the recommended sound levels of 45 dBA. However, educational interventions and warning visual signs seemed effective in reducing sound levels, particularly in the night shift in the NICU station.

## Background

Hearing begins in the 18th week of pregnancy at the earliest and develops around the 28th week [1–3]. The initial postnatal transition following birth is a stressful experience, and exposure to ambient noise in the Intensive Care Units, Neonatal (NICU) may have significant short- and long-term impacts on the infant. The physical environment of NICUs plays a significant role in the overall effect of the offered provided interventions; and careful attention has to be paid to the environment in order to move toward better to improve the treatment of the infants [4]. One important element that must be considered in the physical environment of NICUs is noise. Noise refers to any unwanted sound that interferes with adaptive performance, and causes psychological and physiological distress [5,6].

Noise control is important for the neurobehavioral development of newborns, especially in relation to the brain development of high-risk infants [1]. Environmental noise has been shown to contribute to infancy infantile problems in areas such as the cardiovascular system, blood pressure and heart rate, respiration respiratory system, oxygen saturation, and as well as the lingual, sound and sensorineural development. Apnea decrease in hypoxia-based brain perfusion, and sleep disorders have also been shown to be correlated with noise [7].

Many studies have shown that sound levels in the NICU often exceed the standard prescribed sound levels for infants [7,8]. Because of the infant's reduced autonomic and self-regulatory mechanisms, which deny preventing them the ability to properly process and filter noise stimuli, they are more vulnerable to increased noise levels [9]. An environment free of excessive noise has been shown to decrease the duration of oxygen supplementation, respiratory support, and overall duration of infant's stay in the NICU [10].

Accordingly, the American Academy of Pediatrics has suggested that noise levels should not exceed 45 dB in the NICU [11]. Similarly, the US Environmental Protection Agency has proposed an average indoor sound level of 45 dB in hospitals to create an appropriate rest and recovery environment for infants who are at high risk. However, studies indicate that the average noise levels in most NICUs range from 50 to 75 dB, with peak levels often reaching 105 dB [12, 13].

The training of NICU medical professionals aimed at for reducing noise was shown has proved to be effective in decreasing noises. Moreover, it would belt would also be helpful to introduce periodic noise control evaluation programs and gain feedback from medical staff in order to increase enhance the effectiveness of noise-reduction policies [14, 15].

We hypothesize that the educational intervention and visual signs, resulting result in noise reduction in NICU. Therefore, since there has been not studied in regards to Meanwhile, no study has dealt with noise assessment in the NICU of Vali-e-Asr Hospital and there is lack of research simultaneously using the lack of simultaneous using of the educational intervention and visual signs for noise reduction in the literature,. Accordingly, the current study was conducted to determine the noise level in the NICU of Vali-e-Asr Hospital of the Birjand and University of Medical Science - with regard to with a special focus on monitoring the effects of educational intervention and the use of visual signs on noise control. The main hypothesis of this study is that providing training to health professionals and care workers in the NICU would decrease reduce noise levels.

## Methods

### 2-1 Study design and participants

This quasi-experimental study (before-after study) was conducted in the NICU of Vali-e-Asr Hospital, Birjand, Iran between March and April 2016. A total of 21 participants were recruited including six NICU doctors and fifteen hospital staff who could enter the NICU. They were educated about the hazards of increased sound levels in the NICU based on ISO 9612 standards.

### 2-2 Selection criteria

The entry criteria included consent of the staff and physicians for participation in this study (**Figure 1**).

### 2-3 Measurements

A digital sound-level meter (TES-1385C model, Taiwan) was used for sound measurement. It was calibrated and placed at a height of 1.5 meters (the usual height at which babies are placed off the ground level in the incubator), at the nurse rooms in the NICU, and the incubator sites.

## **2-4 Outcomes**

The sound levels (including: minimum sound level (Lmin), maximum sound level (Lmax), and equivalent sound levels (Leq)) were recorded daily using digital sound level meter for a week (first stage) in 60 stations including 20 stations in each working shift (morning, afternoon and night).

## **2-5 Intervention**

From the 60 stations, 48 stations were in the NICU, 6 stations at the nursing station, and 6 stations at the incubator sites. In other words, 16, 2, and 2 stations were included in each shift respectively.

The sound level was noted in 20 points of three stations for each shift over three different working shift periods (morning, afternoon, evening). Sound level readings were noted randomly, and the average was taken as the final reading. All of the readings were then noted and monitored during 24h through specifically assigned members in the NICU. To avoid any bias, the staff and doctors were informed that this would be a regular practice in the NICU.

A one-week educational intervention (second stage) was then provided to the resident doctors and staff in the NICU by a pediatrics resident. They were made aware of the hazards of high sound levels in nursery and monitored to correctly take into consideration. A PowerPoint presentation was used to explain the necessity of reducing the sound level by pediatrics. Such information was provided to them in short classes ensuring 100% coverage. The key aims of the educational interventions to reduce sound levels included: 1) reducing the alarm levels of all monitors to a safe hearing level; 2) talking with a low volume just enough to be audible in the NICU; 3) no bedside hand over to be made by nurses and doctors; 4) music volume in the NICU kept below 40 dB; 5) making a habit of promptly taking care of rather than anticipating monitor alarms; 6) all were encouraged to download a sound level app in their mobile phone for the practical purpose of measuring sound levels for personal use; 7) the NICU phone ringer was reduced to a minimal level which would still be audible; 8) posters depicting various sound levels during specific activities were placed in the unit; and 9) at the time of cleaning, workers were requested to minimize unnecessary sounds, as Bhat and Bisht also suggested [16].

After this interventional period, the sound level was noted again in a similar format for one week (third stage). The final and fourth stage comprised the post-educational intervention and the installation of visual signs, including colorful flags and posters to highlight the importance of sound levels to the staff of NICU.

## **2-6 Statistical analysis**

Data from measurements were transferred to Excel and then to the SPSS program. SPSS 18 (SPSS Inc., Chicago, IL, USA) was used for data analysis. A two-sided p-level of <0.05 was considered statistically significant.

## Results

Out of the 60 stations, 48 stations (80%) were in the NICU, six stations (10%) were at the nursing station, and six stations (10%) were at the incubator sites.

The mean  $\pm$  SD of sound levels before intervention, after one week of after the intervention and after the installation of the visual signs installation period is shown in Table 1. Analysis during the pre-intervention period of one week by the ANOVA and the Bonferroni correction test revealed significant differences in the sound levels ( $F = 3.13$ ,  $p = 0.047$ ) compared to before and after the pre- and post -intervention at different time periods.

There was a significant difference in the means of the sound level between Stages 2 and 3 ( $P = 0.009$ ) and a significant decrease reduction in the level of sound between Stages 2 and 3. As illustrated presented in Table 1, the minimum sound level ( $L_{\min}$ ) after the intervention, showed a significant decrease ( $p = 0.001$ ). However, the maximum sound level ( $L_{\max}$ ) in the three study periods was not statistically significant.

Table 2 compares the means of  $L_{\text{eq}}$ ,  $L_{\max}$ , and  $L_{\min}$  in three different working shifts. As indicated in Table 2, there was no significant statistical difference in the morning and afternoon shifts in the  $L_{\max}$ . However, in the night shift, there was a significant decrease ( $p = 0.045$ ) vis-à-vis compared with the three different study periods, as well as in the pre- and post-intervention phases ( $p = 0.04$ ).

In the afternoon shift, a significant increase in the  $L_{\text{eq}}$  was seen before and after the intervention ( $p = 0.017$ ). In the night shift, a significant decrease decline in the  $L_{\text{eq}}$  was seen before and after the intervention ( $p < 0.001$ ).

The means of  $L_{\min}$  in the morning and night shifts in the three different study periods indicated a significant decrease fall ( $p < 0.05$ ), while in the afternoon shift, the minimum sound levels showed a significant increase which was significant before and after the intervention ( $p = 0.046$ ).

Table 3 compares the means of  $L_{\text{eq}}$ ,  $L_{\min}$ , and  $L_{\max}$  at three different stations and clearly indicates that  $L_{\min}$  in the nurse and incubator stations  $L_{\min}$  did not indicate a significant statistical difference in the three study periods. However, in the NICU station, a significant decrease was observed ( $p = 0.014$ ). Further,  $L_{\text{eq}}$  in the nurse nursing and incubator stations, did not show any significant statistical difference and, as with  $L_{\min}$  in the NICU station, a significant statistical decrease reduction was shown observed ( $p = 0.015$ ). Moreover Finally, in  $L_{\max}$  there were no statistically significant statistical differences in the three stations.

## Discussion

After the first educational intervention, no significant difference was reported. However, after the second intervention, which was the installation of visual signs, a significant difference in the  $L_{eq}$  was observed. Nevertheless, the role of the educational intervention before the installation of visual signs is not completely devoid of importance as it is useful in reducing the  $L_{eq}$ . It could be used as a supplementary aid for preparation of the second intervention. However, despite the reduction of  $L_{eq}$  after the second intervention, the  $L_{eq}$  still did not match the international standard requirements. In a study in 2017, the  $L_{eq}$  in NICU was reported to be equivalent to the  $L_{eq}$  in a restaurant; however, but with staff training and other interventions (e.g. reducing alarm sound and determined alarm period), the  $L_{eq}$  was reduced by 3dB [17]. After the overall comparison of  $L_{min}$  and  $L_{max}$ , before and after the educational intervention, and right after the visual signs' intervention,  $L_{min}$  indicated a significant decrease but  $L_{max}$  did not indicate a statistically significant difference.

Based on the current available studies,  $L_{eq}$  before the intervention was far above the international standards. Increased incubator  $L_{eq}$  could be due to the use of inappropriate materials for the incubators in terms of sound absorption as well as sound transmission or the working attitude of the staff (e.g. placing things on the incubator or opening/closing the incubator lid), As which is in line with the findings of Nogueira et al. [18] has attained a similar result. These results are also compatible with the results of Slevin et al. [19] at the Dublin hospital, Ireland where the sound level at normal conditions was 58 dB and at during silence, period decreased to 54 dB. Also, our results were matched with the results studied by Elander and Hellstorm [20] in Sweden. They investigated the effect of nurses' education on reductions in sounds intensity decrease and its effect on infants hospitalized at NICUs". and The education could significantly decrease contribute to diminished the average intensity level average of sounds intensity level from 57 dB to 49 dB and control the sound [20]. Other studies [17, 21–24] such as Valizadeh et al. [24] study measured the mean values of  $L_{eq}$  and  $L_{max}$  as 63.46 dB and 71.30 dB, respectively, which states suggesting that noises in NICU were higher than the standard required level ( $L_{eq} < 45$  dB, and  $L_{max} \leq 65$  dB).

The data analysis based on working shifts has shown indicated that after the first and second interventions  $L_{max}$  decreased significantly in the night shifts and while  $L_{eq}$  in the afternoon shift was increased significantly. This indicates that the results might be more due to the finding might mainly be attributed to the time period than related to the interventions. Nonetheless, the  $L_{eq}$  mean was lower in the afternoon shift compared to than in the morning and night shifts was lower. In many studies [25–27], noise level measurements were significantly greater during the day shifts than during the night shifts. In these studies, noise levels during shift changes and/or physician rounds were significantly increased higher as compared with those during all other times of the day or night. Conversely, Lahav [28] found no significant difference in noise levels between nighttime and daytime or between shift changes/physician rounds.

With regard to  $L_{eq}$  in the afternoon shift, Almadhoob and Ohlsson [29] showed a finding similar to this study, which could be due to the lower stress levels and work loads of this shift. Similar results with regard to  $L_{min}$  and  $L_{max}$  were obtained in both the morning and night shift after the first and second interventions which indicated revealing a significant decrease in  $L_{eq}$ . When comparing the level of  $L_{min}$  in across different stations, the nurse and incubator stations did not show any significant increase, but the NICU station showed a significant decrease reduction after both interventions. Byers et al. [30] found that the newer incubators (purchased in or after 1999) provided approximately 4 dB of noise reduction in comparison with noise levels associated with radiant warmers and older incubators (purchased between 1990 and 1994). In addition, the results of Byers et al. [30] study also indicated significantly lower noise levels in the newer renovated NICU as compared with the levels in the older NICU. There have been similar results in the  $L_{eq}$  as well a slight difference in the NICU station, which showed a significant decrease drop after the second intervention.

In spite of a significant reduction in noise, more interventions and control strategies in line with WHO, particularly in the morning shift, are required. Bringing Emulating the NICU environment design close to a single-room model, as well as developing better sound control strategies in such an environment (e.g. sound-absorbing materials on the interior surfaces of the section and incubators to guide sound behavior) could lead to significant improvements. As In this regard, Ramesh et al. [32] stated that the sound levels could decrease up to 9.58 dBA by the implementation of implementing sound noise levels reduction protocols such as separation of rooms with glass and aluminum partitions. Future research could examine the impact of these strategies with a proper engineering design. In addition, the role of customized earpads can be investigated to protect infants from over-exposure to noise. As the potential study limitations, it was planned not the plan was not to inform health professionals about the study before it started its beginning in order not to influence affect the noise measurement results before the interventions. However, some health professionals were informed about the study while informing administrators for the institution's permission. The failure of a group of doctors to attend the training due to their heavy workloads led to a decrease reduction in the number of trained doctors.

## Conclusions

Noise control training for health professionals who work in NICUs is an effective, affordable and practical way of reducing noise. Based on the results, noise in our NICU was more greater than the recommended sound levels of 45 dBA by the American Academy of Pediatrics, and there is still a huge gap discrepancy between our NICU environment and the international standards in terms of the sound level and its distribution, as other also found by another study in Iran [24,31]. However, educational interventions and warning visual signs for doctors and hospital staff significantly reduced the sound levels particularly in the night shift in all stations. These interventions could apply be applied in any NICU with maximum effect at minimum costs.

## Declarations

*NICU*: Neonatal Intensive Care Unit

*Lmin*: minimum sound level

*Lmax*: maximum sound level

*Leq*: equivalent sound levels

#### 7–1 Ethics approval and consent to participate

The study was approved by the ethics committee of Birjand University of Medical Sciences (IR.BUMS.REC.1395.235). The study protocol was explained for all the participants who subsequently signed the informed consent.

#### 7–2 Consent for publication

The participants' information was kept confidential. All procedures were approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Informed consent was assessed prior to the intervention. Details that disclose the identity of the subjects under study were omitted.

#### 7–3 Availability of data and materials

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

#### 7–4 Competing interests

The authors declare that they have no competing interests.

#### 7–5 Funding

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## Tables

Variables	N	Leq ( ± SD)		
und levels before intervention	60	54±4.9	62.24±6.24	47.42±5.27
und levels after intervention	60	54.3±2.6	66.31±6.62	47.31±2.47
und levels after Visual sings	60	52.8±3.1	65.23±6.66	45.48±2.39
VA/ Bonferroni correction test	-	F=3.13		F=5.23
		P= 0.047*	F=0.57	P=0.007*
		2 and 3: p=0.009*	P=0.57	1 and 3: P= 0.023* 2 and 3 P= 0.001*

**Table 1.** Comparison of the mean of the equivalent sound levels ( $L_{eq}$ ), as well as the minimum ( $L_{min}$ ) and maximum ( $L_{max}$ ) sound levels in the three studied periods

Working shifts	N	Before	After	After visual signs	ANOVA /	ANOVA /	ANOVA /
		intervention	intervention	intervention	Bonferroni Test Lmax	Bonferroni Test Lmin	Bonferroni Test Leq
a) Morning	20	Lmax:	65.9±6.6	68.2±7.3	F=1.46	F=5.11	F=0.21
			64.9±7.1	48.4±2.5	P=0.24	P=0.011*	P=0.81
		Lmin:	55±2.9	54.3±3.6		A and C: p=0.03*	
		Leq: 55.1±5.5				B and C: p<0.001*	
b) Afternoon	20	Lmax:	65.6±6.5	64.5±5.9	F=0.81	F=5.19	F=5.02
			66.9±5.9	46.6±2.4	P=0.45	P=0.01	P=0.45
		Lmin:	53.7±2.4	52.3±2.4		A and B: p=0.046*	1 and 2: p=0.017*
		Leq: 50.7±4.3					
c) Evening	20	Lmax:	67.4±6.9	63±5.8	F=3.36	F=7.94	F=41.1
			66.8±5.8	46.4±2.3	P=0.045*	P<0.001*	P<0.001*
		Lmin:	54.3±3.3	51.8±2.8		A and B: p=0.009*	1 and 2: p= 0.025*
		Leq: 56.3±2.8				A and C: p<0.006*	1and 3: p<0.001*

**Table 2.** The comparison of the means of the equivalent sound levels ( $L_{eq}$ ), and the minimum ( $L_{min}$ ), and maximum ( $L_{max}$ ) sound levels in the three working shifts

Stations	N	Before intervention	After intervention	After visual signs intervention	ANOVA / Bonferroni Test Lmax	ANOVA / Bonferroni Test Lmin	ANOVA / Bonferroni Test Leq
<b>I) NICU</b>	48	Lmax: 65.4±5.5 Lmin: 47.6±5.1 Leq: 54±5	65.3±5.7 47.5±2.6 54.1±2.7	64.3±6 45.6±2.5 52.4±3.1	F=0.53 P=0.59	F=4.48 P=0.014* I and III: p=0.032* II and III: p<0.005*	F=3.46 P=0.036* II and III: p= 0.015*
<b>II) Nurse station</b>	6	Lmax: 70.2±10 Lmin: 44.2±3.8 Leq: 53.8±5.6	75.1±7.6 45.9±2.1 56.5±4.4	74.5±6.6 44.3±1.4 56.4±2.2	F=0.53 P=61	F=0.86 P=0.45	F=1.24 P=0.33
<b>III) Incubators</b>	6	Lmax: 68.9±6.1 Lmin: 48.9±7.3 Leq: 54.6±4.1	65.5±6.9 47.5±1.6 54±2.9	63.4±5.2 45.9±1.7 52.5±1.3	F=1.24 P=0.33	F=7.94 P=0.52	F=0.64 P=0.55

**Table 3.** The comparison of the mean of the equivalent sound levels ( $L_{eq}$ ), as well as the minimum ( $L_{min}$ ) and maximum ( $L_{max}$ ) sound levels at three different stations

## Figures

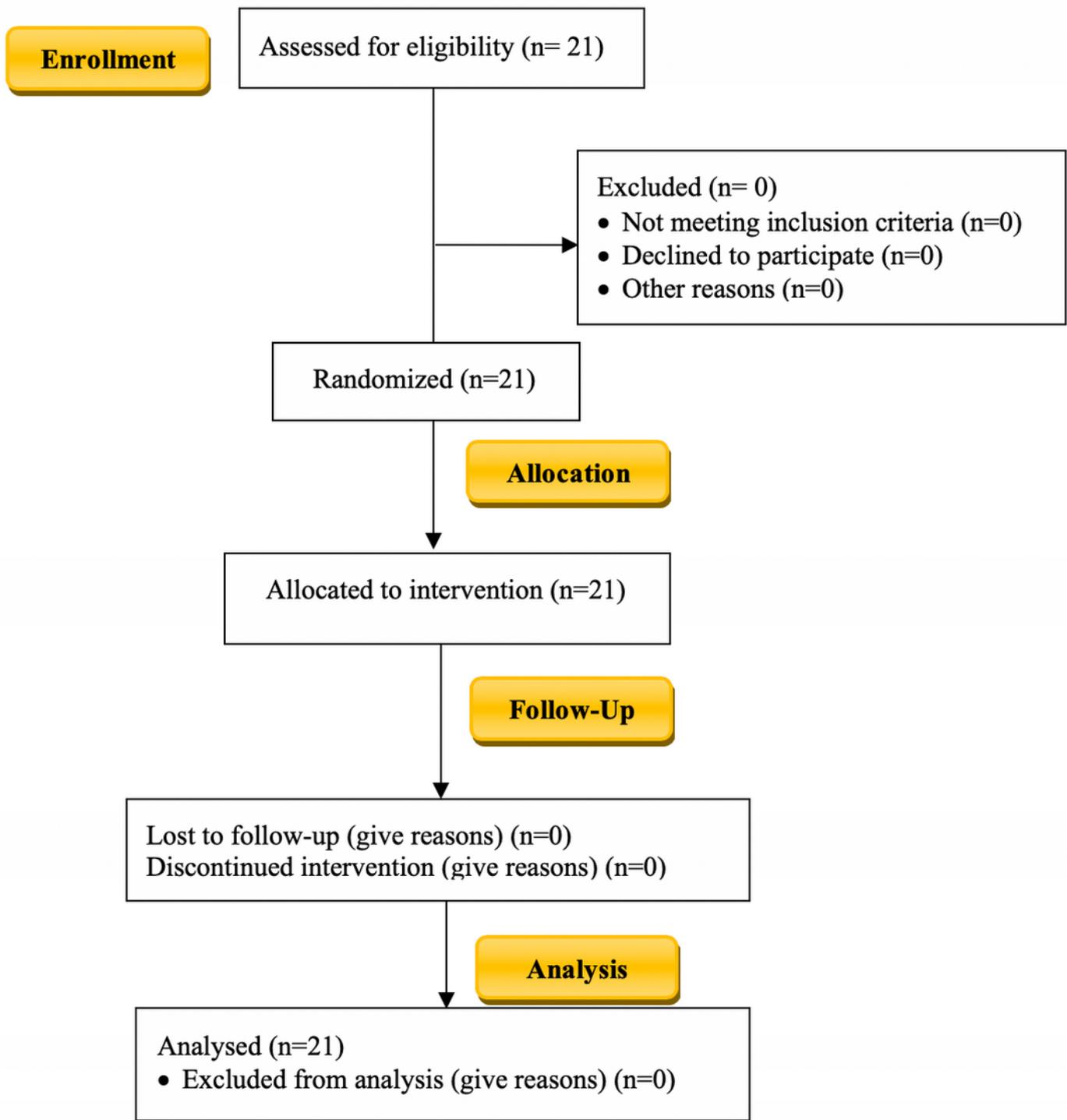


Figure 1

CONSORT 2010 Flow Diagram of the study