THE ARCHITECTURE DESIGN CHECKLIST OF CLASSROOMS FOR CHILDREN WITH COCHLEAR IMPLANT IN REHABILITATION CENTERS

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ABSTRACT

This study explores the design of rehabilitation classrooms for children with cochlear implants (CI) aged one to six years old. It compares preschool classrooms for healthy students and children with CI. The research focuses on the importance of architectural elements such as layout, materials, ventilation, lighting, acoustics, and colors in supporting children with CI's normal life and integrating them into the preschool community. The study includes a questionnaire from parents, teachers, psychiatrists, doctors, architects, and acoustics engineers. The research concludes with a design checklist for the classroom's layout, furniture, colors, materials, shape, lighting, and ventilation.

KEYWORDS: Cochlear Implant (CI), Rehabilitation Center (RC), Classroom, Architecture Design, Design Checklist

1. INTRODUCTION

For every 1,000 live births, one to two individuals are born with congenital deafness (NICE, 2019). Cochlear implants (CIs) are frequently recommended for deaf and hard of hearing (DHH) children who have profound deafness (between 71 and 90 dBHL). In Egypt, there are roughly 1.2 million deaf and hard-of-hearing Egyptians aged five and older (Cairo Deaf Unit, 2020). The Article Disability in North Africa states that health and rehabilitation services for children and people with disabilities are scarce, of poor quality, and fall short of meeting all their requirements [2].

Rehabilitation and training are crucial for children with cochlear implant (CI) hearing loss to achieve optimal hearing [1,3]. A secure, reassuring, and loving classroom environment is essential for fostering a supportive learning environment. CI is the safest and most successful treatment for recovering hearing in severe-to-
profound sensorineural hearing loss (SNHL), allowing children to develop speech perception, speech production, and language skills [4].

The development of CI devices, including waterproof ones like Neptune and two-mic devices, has improved children's development and rehabilitation. However, implanting these devices can lead to cognitive/learning disabilities, global development delays, speech recognition issues, seizures, and autism [29]. A study suggests that architectural strategies for classrooms should consider accessibility, furniture arrangement, flooring, materials, insulation, ventilation, lighting, colors, textures, and acoustics for children with CI difficulties [6].

Current classrooms for children with CI lack essential rehabilitation elements like natural lighting, thermal comfort, noise reduction, color, texture, flooring material, and furniture arrangement [7]. Traditional classrooms have design flaws, such as uncomfortable materials and distant restrooms, which make children feel depressed and uncooperative. Plain tiles without rugs, lack of insulation, fans, and inadequate natural lighting contribute to discomfort. Psychological comfort is also lacking due to excessive color usage and lack of plant-related spaces. Establishing architectural specifications and guidelines that consider the mental and physical needs of these children is crucial [8].

2. Literature Review

Cochlear implantation (CI) has been proven beneficial for oral language development and integration into mainstream classrooms. Young children with CIs develop similarly to hearing children, and their environments should be comfortable to improve their psychological state and well-being. Previous research has focused on physical, psychological, and medical aspects of CI students' behavior, but there is a lack of study on classroom layout for this group.

1. Mohamed El Shazly [9], president of the Egypt Cochlea 2018 conference and Wadi El Neel Hospital Cochlear Implant Unit, reported that over 8,000 Egyptian children require CI surgery annually, with 1,500 undergoing cochlear implants. Around 80% of these children may have Autism or Epilepsy due to inadequate environment.
2. Hossam El-Dessouky's study [10] reveals that Egyptian Arabic-speaking children exhibit remarkable auditory abilities in different cochlear age groups. They develop detection skills at 1 to 6 months, identification, short-term memory, and discrimination skills at 7 to 12 months, all auditory skills at 13 to 18 months, phonological solid patterns at 19-24 months, short-term memory improvement at 25 to 30 months, and complete auditory skills at 31 to 36 months. This suggests that Egyptian children acquire all auditory, detection, and identification skills after 36 months of cochlear implantation.

3. Marcus Adrian [11], studies the needs and requirements for deaf children and hearing aids. He stated, in his conference with TEDx, his experiences in designing a nursery for those children achieving a good quality environment through the lenses of design. He reported his findings of the main lenses of design as guidelines for any space with deaf children or hearing aids, such as physical ability, sensory ability, cognitive ability, and social ability. These four main design lenses are the essential steps for a healthy and effective space for deaf children or hearing aids.

4. Lauren M. Larrick's [12] thesis explores the early phases of the Computer-Induced Learning (CI) process, providing a foundation for designing a sound-based rehabilitation tool. The study outlines the progression of auditory, speech, and language abilities, similar to a learning hierarchy. Larrick suggests understanding the user's journey of the implanting process to transform it into a learning tool through architecture.

5. Gill Hawkins [13] provided non-statutory recommendations on setting up and developing facilities for both new and existing schools in England, all of which will contain at least a few students with special educational needs and disabilities. The study discusses all the necessary design requirements for all schools generally and for learning and social spaces, particularly for primary, elementary, and secondary stages. The findings are a checklist for designing a school classroom for children with special educational needs and disabilities.

6. Awatef Ali Bivarchi's study [7] examines the factors affecting rehabilitation and education in children with CI. Factors include individual-level variables like
implantation age, inner ear morphology, and device usage. Interpersonal and organizational variables include low socioeconomic status, family support, and specialist shortages. Environmental and policy-level problems include a lack of community knowledge, unclear educational strategies, and difficulties in implementing hearing screening programs.

7. Uma G. Soman [14] explained the numerous educational and rehabilitation alternatives available to children with CI while focusing on the necessity of a cooperative approach to rehabilitation planning and execution. Decisions about these possibilities are made on an individual basis, taking into account the expectations and preferences of the family as well as the patient's age during implantation. Additionally, a review of laws pertaining to the education of kids with hearing loss is given.

8. Jiaojiao Wu's study [15] compares the educational placement and adjustment of 43 children with CI implants in China and the Czech Republic. The research found that children adapt to placements based on environmental conditions, interpersonal relationships, and academic achievement. Educational options include regular classes, resource rooms, deaf schools, institutions, and homestays. The study found significant differences in children's overall school adjustment between the groups, with communication barriers and low academic achievement being the primary factors causing students to switch to deaf schools.

2.1 Cochlear Implant: Clinical Overview

Children with cochlear implants are aware of what is going on around them. Yet, their communication skills and comprehension are restricted by their muteness and limited hearing skills in their first habilitation phases. People may feel irate and agitated as a result of not being able to express their demands and emotions clearly due to speech difficulties. The effects of a cochlear implant on children are issues in their:

- **Social abilities**: focuses on issues in communication, engagement, making friends, and interaction, assertiveness, gaining confidence, resolving issues, managing anger and anxiety,
- **Sensory abilities**: includes problems in attention due to visual barriers or noise and lack of thermal comfort
- **Cognitive abilities**: includes difficulties in learning, language, thinking, participation, behavior, and decision-making
- **Physical abilities**: encouraging movement and involvement with objects and space

Children with CI need a comfortable environment that meets their needs and requirements. Early implantation makes rehabilitation easier, allowing them to integrate into their environment [18]. Rehabilitation prepares children aged two to six for primary education, which is crucial for their development. The approach to teaching at this stage should focus on the needs of the child, including love, kindness, and opportunities for play, among other educational criteria.

3. **Methods**

This study compares classroom design for children with hearing impairments (CI) to healthy preschool children using a quantitative research technique. A questionnaire instrument is used to understand CI needs and issues in rehabilitation classrooms. A checklist detailing architectural factors for a rehabilitation classroom is provided, and case studies (Nida for Deaf and Hearing Weakness Rehabilitation and Maryland School for the Deaf) are analyzed to identify benefits and weaknesses.

3.1 **Research Problem**

Despite the knowledge of rehabilitation space design standards, there is a lack of studies examining the effect of RC’s classroom design on children with CI, which is addressed as a research gap.

3.2 **Research Approach**

The research uses a comparative approach to assess the interior design of RC classrooms for children with CI, aiming to provide psychological and mental comfort by understanding their needs, identifying design requirements, and developing a design checklist.
3.3 The Space Sample Dimensions

The study compared a preschool classroom at Sager International School (SAS) in Riyadh, Saudi Arabia, and a classroom for children with cerebral palsy (CI) at Balloons Nursery in Cairo, Egypt. Both classrooms, as shown in Fig. 1 and 2, have dimensions of 6.50 m * 8.00 m and are oriented south-north. SAS's classroom features ceramic flooring tiles, windows, air conditioning, and thermal insulation, while Balloons Nursery's CI classroom has one main door, restrooms, outdoor space, and air conditioning.

3.4 Hypothesis

H1: The space architecture and environment of preschool classrooms are changed by significant architectural strategies for children with CI.

4. Difficulties influencing children with CI and its effect on the classroom design

Implanting a cochlear implant in children aged 0-6 can lead to various disabilities, including cognitive/learning disabilities, global development delay, speech recognition issues, seizures, and autism [21]. These disorders affect their mental and physical characteristics, necessitating classroom design that considers these children's needs.
4.1 Cognitive/Learning Disabilities

Children with learning disabilities typically struggle with cognitive function, emotional issues, and behavior adaptation. However, since infants with learning disabilities were discovered to be born deaf, these significant issues remain challenging to pinpoint. Table 1 shows the impact of cognitive/learning disabilities on children with CI inside a classroom. Furniture arrangement is one of the most essential factors as children have difficulty paying attention and concentrating to understand what is occurring around them [23].

4.2 Global Development Delay

Suppose a child under the age of five shows obvious evidence of a developmental delay but cannot be assessed for a more precise diagnosis due to their age. In that case, they are labeled with Global Development Delay, a type of intellectual impairment [24]. Table 2 indicates that the materials used for classroom flooring affect the movement of CI children with global development delay.

Table 1 The impact of cognitive/learning disabilities on children with CI inside a classroom (source: authors).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Furniture Arrangement: Using rounded linked tables is better for both children’s safety and sense of comfort.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Nature</td>
<td>Healthy Child</td>
</tr>
<tr>
<td>Design</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>Traditional arrangement with separate desks facing teacher’s desk and board.</td>
</tr>
</tbody>
</table>
Table 2 The impact of classroom flooring materials on CI children with development delay (source: authors).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Flooring Material: using soft, non-slippery material to prevent injuries or accidents, such as rugs, mats, or vinyl, must be used for children inside a classroom as it is much safer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Nature</td>
<td>Healthy Child</td>
</tr>
<tr>
<td>Design</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>Ceramic tiles are not safe for children due to their slipperiness and hardness, thus causing injuries for kids when falling.</td>
</tr>
</tbody>
</table>

4.3 Speech Recognition

The difficulties in recognizing speech and understanding are faced by either genetic or environmental factors [25]. Table 3 shows the impact of speech recognition difficulties in the design of the restrooms and furniture placement inside a classroom for children with CI.

Table 3 The impact of speech recognition difficulties in the design of the restrooms and furniture placement inside a classroom for children with CI. (source: authors).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Restrooms: there must be at least two restrooms inside a classroom. When restrooms are distant from the classroom, it is exceedingly difficult for CI children to use it, necessitating the need of an aid.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Nature</td>
<td>Healthy Child</td>
</tr>
<tr>
<td>Design</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td>Restrooms are far from the classrooms and not inside them, which makes it difficult for them to reach.</td>
</tr>
</tbody>
</table>
4.4 Seizures Activity

Despite the fact that cochlear implantation is often well accepted and without problems, a tiny percentage of patients may experience soft failure signs and seizures [26]. Table 4 shows how design factors elements of colors and size affect the characteristics of children with CI and reduce the probability of any seizures activity.

Table 4 The impact of colors and classroom space area on the CI children with seizures activity. (source: authors).

| Color: colors can affect the children’s mood and state of comfortability and calmness. Cold colors, such as blue and green, give a mood of happiness and relaxation, while warm colors, such as red and orange, give a mood of fear, intensity, and anger [27] [28]. |
|---|---|
| Child Nature | Healthy Child | CI Child |
| Specification | The red color in the classroom, whether as paint or objects, causes students to act furiously and gives a feeling of anxiety. | Using few and more comfortable colors such as white, off-white, or beige for walls or furniture is essential for children with CI to avoid any seizures activities. |
| Strategy | Size: Class size is an educational tool that describes the average number of students in each educational space [30]. The average amount of educational space per person is 1.5 to 2 square meters. |
| Design | The classroom, with dimensions 6.50 m * 8.00 m, occupies 12 students. | The classroom, with dimensions 6.50 m * 8.00 m, occupies 8 students. |

NOTE: a small number of students inside a classroom is much better than a large amount to facilitate the interactions between the children and the teachers and to avoid distractions and discomfort [31].

4.5 Learning Space Discomfort

The environmental factors elements of ventilation, lighting, insulation, and acoustics may cause physical and psychological discomfort inside a classroom for children with CI that affects their performance and behaviors. Table 5 shows how the design of the classrooms may cause a learning space discomfort [16].
4.6 Autism

Acoustics is one of the aspects that has the most significant influence on autistic students' learning performance [20]. Table 6 shows how insulation and acoustics design impact children with CI.

Table 5 The impact of ventilation and lighting in a classroom on children with CI. (source: authors).

<table>
<thead>
<tr>
<th>Design</th>
<th>Ventilation: An essential prerequisite for mental health and subjective well-being is clean air [5]. The higher ventilation rate may greatly enhance kids' ability to study.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Child Nature</strong></td>
</tr>
<tr>
<td>Specification</td>
<td>The windows from the north side allow natural ventilation and refresh the classroom air.</td>
</tr>
<tr>
<td>Strategy</td>
<td>Lighting: Despite the fact that the two types of lighting can be combined to provide adequate lighting for a variety of tasks in architectural spaces, it has been found that natural lighting is preferable to artificial lighting in settings like classrooms due to the psychological and physiological advantages it offers students. [19].</td>
</tr>
<tr>
<td>Design</td>
<td>Insulation and Acoustics: educational spaces must be insulated (walls and floors) to avoid noise and disturbance that may cause cognitive difficulties.</td>
</tr>
<tr>
<td>Specification</td>
<td>Natural lighting is essential in any educational space.</td>
</tr>
</tbody>
</table>

Table 6 The impact of classroom insulation and acoustics on autistic children with CI. (source: authors).
5 Case Studies

5.1 Nida for Deaf and Hearing Weakness Rehabilitation

As Fig. 3 shows, Nida is a rehabilitation center for deaf and hard-of-hearing children in Cairo, Egypt. The school accepts students from two to six years old, teaching them different learning skills and rehabilitating them to integrate into normal life for the Primary Stage in School. The selection has determined the optimum design for a classroom that students with CI inhabit as a case study nationwide to distinguish between classroom design factors.

<table>
<thead>
<tr>
<th>Design</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise in the classroom can come from external sources, such as background noise, or directly from students as activity noises [22].</td>
<td></td>
</tr>
<tr>
<td>Using acoustical wall panels to reduce noise reflection for children with CI.</td>
<td></td>
</tr>
</tbody>
</table>

![Design elements used at Nida Rehabilitation Classrooms](image)

Figure 3 Design elements used at Nida Rehabilitation Classrooms
5.2 Maryland School for Deaf

The Maryland School for the Deaf is a multicultural, bicultural community that offers an equal and exceptional education in a supportive, stimulating, and demanding atmosphere to guarantee students achieve personal excellence and develop into responsible lifelong learners. By providing instructional, developmental, and extracurricular activities, the school helps students improve their intellectual and social skills, as shown in Fig.4. Two campuses exist at the school: one in Frederick and one in Columbia. Deaf and hard-of-hearing students can enroll at the Frederick Campus from kindergarten through grade 12.

6. Classification of Elements in Rehabilitation Centers

Students with visual impairments (CI) require clear visual accommodations to access the curriculum and language in the educational environment. They must maintain visual attention to teachers, translators, and peers to promote comprehension. These accommodations reduce the need for students to split their focus between...
instructors, peers, handouts, and slides [8]. Classroom elements, as shown in fig. 5 and 6, are divided based on placement, with walls having 50% importance, floors having 20%, and ceilings having 30% importance. Specialists in the CI field prepare questionnaires to identify sub-elements scores within a classroom.

7. Questionnaire Survey

The questionnaire includes 48 questions divided into three categories (wall, floor, and ceiling). Each question was given a score according to its importance depending on the three classifications of design, making a 100% score. 31 persons, 6 Children Audiology Doctors, 8 Communication Specialists, 5 Sound Engineers, 7 Children Neurology and Psychology Doctors, 5 Teachers, answered the questionnaire. The results show that each element has a particular percentage of importance inside a rehabilitation classroom for children with CI. The answers varied, but all ranged in high scores with a slight difference according to the respondents' points of view. Fig. 7, 8, and 9 show the summary of the responses and statistics.

Figure 5 Elements Classification inside a rehabilitation classroom

![Figure 5 Elements Classification inside a rehabilitation classroom](image)

Figure 6 Elements Percentage According to their importance

![Figure 6 Elements Percentage According to their importance](image)

Figure 7 Ceiling elements results

![Figure 7 Ceiling elements results](image)
8. Results and Discussion

Previous research on students with intellectual disabilities primarily focused on physical and psychological aspects, leaving it challenging to find relevant references. Therefore, our study aimed to gather relevant material from references in architecture and medicine. Table 7 provides the study findings as a design checklist for a classroom designed for children with CI using architectural techniques. The checklist, based on studies, questionnaires, field visits, and children's behaviors, consists of floors, ceilings, and walls. It aims to create a healthy, conducive environment for learning and development, ensuring a conducive environment for children with CI. *(according to the British Code for deaf Children and hard of hearing)*

Table 7 Design checklist

<table>
<thead>
<tr>
<th>Items</th>
<th>Percentage</th>
<th>Specification</th>
<th>Over design 0%</th>
<th>Optimum 50%</th>
<th>Sub-optimum 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Floor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Design</td>
<td>6%</td>
<td>The combined Activity and Withdrawal spaces must provide a minimum of 3.25 m² of unoccupied space per child.</td>
<td>0-2.0m²</td>
<td>2.0 m² – 3.0m²</td>
<td>3.25m²</td>
</tr>
<tr>
<td>Orientation</td>
<td></td>
<td>The main aspect of orientation is to maintain sunlight and cool natural air inside a classroom in the northeastern direction.</td>
<td>South East/South West</td>
<td>North West</td>
<td>North East</td>
</tr>
<tr>
<td>Fixtures and Furniture</td>
<td>6%</td>
<td><strong>Benches:</strong> At least one bench must be high enough to accommodate wheelchair access and must be 0.60m high for children ages 0 to 4 years and 0.72m high for children ages 5-8 years.</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>
| 1% | **Cabinet** surfaces are made of durable, low-maintenance laminate, including lockable cabinets for all objects stored inside a classroom.  
**Bag Storages**: Pigeon hole joinery units with dimensions of 0.30 m wide by 0.30 m high and a maximum height of 1.00 m. Bag hangers with covering shelves may also be used if they are within close proximity of the activity area. An option is hooks, which must have protective wood coatings. The section with the children's restrooms is not where the bag storage space should be. |
|---|---|
| **Orientation**: According to the space function, it is the orientation of the furniture. Flexible moving furniture must be provided for different activities and purposes inside a classroom.  
/ | Fixed | Some are fixed, and others are movable | Movable |
| **Textures**: avoid rough and sharp textures for the safety of the children. | | | |
| **Floorings** | **Use** anti-slippery materials such as rugs, vinyl, carpets, and foam mats that must strike a balance between having some patterning and not being overly light in color (simple cleaning and a reduction in markings showing), as well as in relaxing colors and patterns for kids with severe sensory difficulties. The floor treatments should improve the acoustic qualities of each space | Ceramic | Wooden tiles | Rugs, vinyl, carpets, foam mats |
| **Restrooms** | • At least two restrooms are available with direct access from and to the classroom.  
• The restroom door width is between 0.80 m to 1.00 m for wheelchair access  
• Restrooms include a toilet, a sink, and a shower space. | No restrooms | Restrooms beside the classroom | Restroom inside the classroom |
| **Ceiling** | **Acoustics** | **Floors and wall insulation inside a classroom are used to reduce background noise either from outdoors or indoors. Use acoustics wall panels to avoid reflecting noise back to the children with CI.  
**NOTE**: The cochlear implant audiologist can consult with the education staff to provide specific advice for limiting or preventing static electricity exposure in the classroom. High static electricity levels can harm the cochlear implant's internal and exterior devices, reducing its effectiveness.** | No insulation | One-sided Wall insulation | All-sided wall insulation and wall panels |
| **Ventilation** | **Artificial Ventilation**: Air conditioning or heater adjusted with temperature between 23°C to 25°C.  
**No fans** of any type (ceiling, wall desk, or standalone fan) are inside a classroom. | >20°C / <25°C | 20-23°C | 23-25°C |
| **Height and Structure** | • Clear space without columns or structural elements.  
• Flat walls and ceiling to avoid echoing and noise reflections on children with CI.  
• Clear ceiling height is between 3.0 m to 3.5 m to give the children a sense of comfort and safety. | >3 m / <3.5m | / | 3.0m - 3.5m |
<table>
<thead>
<tr>
<th>Lighting</th>
<th>5%</th>
<th><strong>Artificial Lighting:</strong> a light intensity of 300 to 500 lux according to the International Energy Conservation Code (IECC). Light switches must be positioned between 0.90m and 1.10m above floor level. Light switches feature isolators, so they don't present an electrical threat. The standard is current-generation tubular fluorescent lamps.</th>
<th>&gt;300 lux / &lt;500 lux</th>
<th>/</th>
<th>300 – 500 lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of Ceiling</td>
<td>2%</td>
<td>Acoustic ceiling systems, false ceilings, gypsum.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wall</strong></td>
<td>9%</td>
<td><strong>Boards, smart Boars, Projectors:</strong> Flexible for different orientations and positions. Away from direct window light to avoid blur and glare.</td>
<td>Fixed</td>
<td>/</td>
<td>Movable</td>
</tr>
</tbody>
</table>
| Doors | 8% | - The door width is between 1.00m to 1.20m and height of 2.20m
- Doors adhere to accessibility requirements.
- Viewing panels installed between 0.80m and 1.80m above the floor for visibility and monitoring.
- Fully glazed doors are used in situations where full height visibility from the inside to the outside is required and must have a mid-rail that is between 0.90m and 1.00m above the floor. | Width >1.0m / <1.2m | Width 0.9m-1.3m | Width 1.0m - 1.2m |
| Charts and Display Boards | 6% | **Charts:** not more than 2 charts with cool colors. **Display Boards:** Display boards of various heights are available in all Activity Areas. Avoid placing display boards over heaters and sinks. In order to prevent the usage of pins, display boards are covered with Velcro-compatible material. | <2 charts | / | >2 charts |
| Colors | 15% | **Colors:** avoid warm colors; instead, use cool colors for furniture and walls. Use matte rather than gloss paint on walls to reduce glare. | Warm Colors | / | Cool colors |
| Windows | 4% | **Natural Lighting:** windows of 30% of the room's total area with external sunscreens as slat or roller sunscreen. | 0-10% | 10-25% | 30% |
|  | 4% | **Natural Ventilation:** classrooms are naturally ventilated, offering openable windows or openings, each with a width of 1.0m to 1.5m. Windows openable surface is approximately 10% of the gross surface. | 0-5% openable | 5%-10% openable | 10% openable |
| Alarm signs and signals | 4% | - A silent monitored security alarm system that combines smoke and movement detectors.
- Emergency signs are placed on top of the classroom’s door. (Exist Signs) |  |  |  |

9. Conclusions

Despite the understanding of rehabilitation space design guidelines, there is a shortage of research on the influence of RC classroom design on children with CI, which is identified as a research gap. The study investigated the architectural features of the design of the classroom for children with CI in an attempt to develop a model of
the ideal classroom based on architectural methodologies. The design checklist shows
every architectural and design element in the perfect configuration inside the
classroom for kids with cognitive impairments. Thus, as the hypothesis suggests, there
are significant architectural approaches that affect the design and arrangement of
classrooms for children with CI in rehabilitation facilities.

The checklist concludes each design element that must be available within a
classroom with an accuracy of 100% for the sub-optimum, 50% for the optimum, and
0% for the over-design on the checklist. Therefore, designers aiming to create a
successful and healthy environment for the CI children may benefit from the checklist
by implementing it to assist in satisfying the children’s demands and requirements in
the most optimal way possible.

List of Abbreviations
CI – Cochlear Implant RC – Rehabilitation Center

Ethics approval and consent to participate
This research did not require Institutional Review Board or Committee approval
because the questionnaire held does not report individual cases or case series, rather, it
analyzes the importance of each element of design inside a classroom for CI children
according to each participant's point of view. The participants approved their
participation in the survey without any compensation.

Consent for publication
Not Applicable

DECLARATIONS

Availability of data and materials
The datasets used and analyzed during the current study are available from the
 corresponding author upon reasonable request.

Competing interests
The authors declare that they have no competing interests.
Funding
Not Applicable

Authors' contributions
ES analyzed the theoretical section regarding the CI and the habilitating process. TR performed the questionnaire for the classifications of design elements. YS contributed to designing the checklist and writing the manuscript. All authors read and approved the final manuscript.

Acknowledgments
Not Applicable

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Rehabilitation and training are crucial for children with cochlear implant (CI) hearing loss to achieve optimal hearing [1,3]. A secure, reassuring, and loving classroom environment is essential for fostering a supportive learning environment. CI is the safest and most successful treatment for recovering hearing in severe-to-
profound sensorineural hearing loss (SNHL), allowing children to develop speech perception, speech production, and language skills [4].

The development of CI devices, including waterproof ones like Neptune and two-mic devices, has improved children's development and rehabilitation. However, implanting these devices can lead to cognitive/learning disabilities, global development delays, speech recognition issues, seizures, and autism [29]. A study suggests that architectural strategies for classrooms should consider accessibility, furniture arrangement, flooring, materials, insulation, ventilation, lighting, colors, textures, and acoustics for children with CI difficulties [6].

Current classrooms for children with CI lack essential rehabilitation elements like natural lighting, thermal comfort, noise reduction, color, texture, flooring material, and furniture arrangement [7]. Traditional classrooms have design flaws, such as uncomfortable materials and distant restrooms, which make children feel depressed and uncooperative. Plain tiles without rugs, lack of insulation, fans, and inadequate natural lighting contribute to discomfort. Psychological comfort is also lacking due to excessive color usage and lack of plant-related spaces. Establishing architectural specifications and guidelines that consider the mental and physical needs of these children is crucial [8].

2. Literature Review

Cochlear implantation (CI) has been proven beneficial for oral language development and integration into mainstream classrooms. Young children with CIs develop similarly to hearing children, and their environments should be comfortable to improve their psychological state and well-being. Previous research has focused on physical, psychological, and medical aspects of CI students' behavior, but there is a lack of study on classroom layout for this group.

1. Mohamed El Shazly [9], president of the Egypt Cochlea 2018 conference and Wadi El Neel Hospital Cochlear Implant Unit, reported that over 8,000 Egyptian children require CI surgery annually, with 1,500 undergoing cochlear implants. Around 80% of these children may have Autism or Epilepsy due to inadequate environment.
2. Hossam El-Dessouky's study [10] reveals that Egyptian Arabic-speaking children exhibit remarkable auditory abilities in different cochlear age groups. They develop detection skills at 1 to 6 months, identification, short-term memory, and discrimination skills at 7 to 12 months, all auditory skills at 13 to 18 months, phonological solid patterns at 19-24 months, short-term memory improvement at 25 to 30 months, and complete auditory skills at 31 to 36 months. This suggests that Egyptian children acquire all auditory, detection, and identification skills after 36 months of cochlear implantation.

3. Marcus Adrian [11], studies the needs and requirements for deaf children and hearing aids. He stated, in his conference with TEDx, his experiences in designing a nursery for those children achieving a good quality environment through the lenses of design. He reported his findings of the main lenses of design as guidelines for any space with deaf children or hearing aids, such as physical ability, sensory ability, cognitive ability, and social ability. These four main design lenses are the essential steps for a healthy and effective space for deaf children or hearing aids.

4. Lauren M. Larrick's [12] thesis explores the early phases of the Computer-Induced Learning (CI) process, providing a foundation for designing a sound-based rehabilitation tool. The study outlines the progression of auditory, speech, and language abilities, similar to a learning hierarchy. Larrick suggests understanding the user's journey of the implanting process to transform it into a learning tool through architecture.

5. Gill Hawkins [13] provided non-statutory recommendations on setting up and developing facilities for both new and existing schools in England, all of which will contain at least a few students with special educational needs and disabilities. The study discusses all the necessary design requirements for all schools generally and for learning and social spaces, particularly for primary, elementary, and secondary stages. The findings are a checklist for designing a school classroom for children with special educational needs and disabilities.

6. Awatef Ali Bivarchi's study [7] examines the factors affecting rehabilitation and education in children with CI. Factors include individual-level variables like...
implantation age, inner ear morphology, and device usage. Interpersonal and organizational variables include low socioeconomic status, family support, and specialist shortages. Environmental and policy-level problems include a lack of community knowledge, unclear educational strategies, and difficulties in implementing hearing screening programs.

7. Uma G. Soman [14] explained the numerous educational and rehabilitation alternatives available to children with CI while focusing on the necessity of a cooperative approach to rehabilitation planning and execution. Decisions about these possibilities are made on an individual basis, taking into account the expectations and preferences of the family as well as the patient's age during implantation. Additionally, a review of laws pertaining to the education of kids with hearing loss is given.

8. Jiaojiao Wu's study [15] compares the educational placement and adjustment of 43 children with CI implants in China and the Czech Republic. The research found that children adapt to placements based on environmental conditions, interpersonal relationships, and academic achievement. Educational options include regular classes, resource rooms, deaf schools, institutions, and homestays. The study found significant differences in children's overall school adjustment between the groups, with communication barriers and low academic achievement being the primary factors causing students to switch to deaf schools.

2.1 Cochlear Implant: Clinical Overview

Children with cochlear implants are aware of what is going on around them. Yet, their communication skills and comprehension are restricted by their muteness and limited hearing skills in their first habilitation phases. People may feel irate and agitated as a result of not being able to express their demands and emotions clearly due to speech difficulties. The effects of a cochlear implant on children are issues in their:

- **Social abilities**: focuses on issues in communication, engagement, making friends, and interaction, assertiveness, gaining confidence, resolving issues, managing anger and anxiety,
• **Sensory abilities:** includes problems in attention due to visual barriers or noise and lack of thermal comfort

• **Cognitive abilities:** includes difficulties in learning, language, thinking, participation, behavior, and decision-making

• **Physical abilities:** encouraging movement and involvement with objects and space

Children with CI need a comfortable environment that meets their needs and requirements. Early implantation makes rehabilitation easier, allowing them to integrate into their environment [18]. Rehabilitation prepares children aged two to six for primary education, which is crucial for their development. The approach to teaching at this stage should focus on the needs of the child, including love, kindness, and opportunities for play, among other educational criteria.

3. **Methods**

This study compares classroom design for children with hearing impairments (CI) to healthy preschool children using a quantitative research technique. A questionnaire instrument is used to understand CI needs and issues in rehabilitation classrooms. A checklist detailing architectural factors for a rehabilitation classroom is provided, and case studies (Nida for Deaf and Hearing Weakness Rehabilitation and Maryland School for the Deaf) are analyzed to identify benefits and weaknesses.

3.1 **Research Problem**

Despite the knowledge of rehabilitation space design standards, there is a lack of studies examining the effect of RC’s classroom design on children with CI, which is addressed as a research gap.

3.2 **Research Approach**

The research uses a comparative approach to assess the interior design of RC classrooms for children with CI, aiming to provide psychological and mental comfort by understanding their needs, identifying design requirements, and developing a design checklist.
3.3 The Space Sample Dimensions

The study compared a preschool classroom at Sager International School (SAS) in Riyadh, Saudi Arabia, and a classroom for children with cerebral palsy (CI) at Balloons Nursery in Cairo, Egypt. Both classrooms, as shown in Fig. 1 and 2, have dimensions of 6.50 m * 8.00 m and are oriented south-north. SAS's classroom features ceramic flooring tiles, windows, air conditioning, and thermal insulation, while Balloons Nursery's CI classroom has one main door, restrooms, outdoor space, and air conditioning.

![Figure 1 Usual Classroom, Sager International School, Riyadh, KSA](image1)

![Figure 2 CI Classroom, Balloons Nursery, Cairo, Egypt](image2)

3.4 Hypothesis

H1: The space architecture and environment of preschool classrooms are changed by significant architectural strategies for children with CI.

4. Difficulties influencing children with CI and its effect on the classroom design

Implanting a cochlear implant in children aged 0-6 can lead to various disabilities, including cognitive/learning disabilities, global development delay, speech recognition issues, seizures, and autism [21]. These disorders affect their mental and physical characteristics, necessitating classroom design that considers these children's needs.
4.1 Cognitive/Learning Disabilities

Children with learning disabilities typically struggle with cognitive function, emotional issues, and behavior adaptation. However, since infants with learning disabilities were discovered to be born deaf, these significant issues remain challenging to pinpoint. Table 1 shows the impact of cognitive/learning disabilities on children with CI inside a classroom. Furniture arrangement is one of the most essential factors as children have difficulty paying attention and concentrating to understand what is occurring around them [23].

4.2 Global Development Delay

Suppose a child under the age of five shows obvious evidence of a developmental delay but cannot be assessed for a more precise diagnosis due to their age. In that case, they are labeled with Global Development Delay, a type of intellectual impairment [24]. Table 2 indicates that the materials used for classroom flooring affect the movement of CI children with global development delay.

Table 1 The impact of cognitive/learning disabilities on children with CI inside a classroom (source: authors).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Furniture Arrangement: Using rounded linked tables is better for both children’s safety and sense of comfort.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Nature Design</td>
<td>Healthy Child</td>
</tr>
<tr>
<td>Specification</td>
<td>Traditional arrangement with separate desks facing teacher’s desk and board.</td>
</tr>
</tbody>
</table>
4.3 Speech Recognition

The difficulties in recognizing speech and understanding are faced by either genetic or environmental factors [25]. Table 3 shows the impact of speech recognition difficulties in the design of the restrooms and furniture placement inside a classroom for children with CI.

Table 3 The impact of speech recognition difficulties in the design of the restrooms and furniture placement inside a classroom for children with CI. (source: authors).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Restrooms: there must be at least two restrooms inside a classroom. When restrooms are distant from the classroom, it is exceedingly difficult for CI children to use it, necessitating the need of an aid.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Nature</td>
<td>Design</td>
</tr>
<tr>
<td>Specification</td>
<td>Restrooms are far from the classrooms and not inside them, which makes it difficult for them to reach.</td>
</tr>
</tbody>
</table>
4.4 Seizures Activity

Despite the fact that cochlear implantation is often well accepted and without problems, a tiny percentage of patients may experience soft failure signs and seizures [26]. Table 4 shows how design factors elements of colors and size affect the characteristics of children with CI and reduce the probability of any seizures activity.

Table 4 The impact of colors and classroom space area on the CI children with seizures activity. (source: authors).

<table>
<thead>
<tr>
<th>Child Nature</th>
<th>Healthy Child</th>
<th>CI Child</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Specification</strong></td>
<td>The red color in the classroom, whether as paint or objects, causes students to act furiously and gives a feeling of anxiety.</td>
<td>Using few and more comfortable colors such as white, off-white, or beige for walls or furniture is essential for children with CI to avoid any seizures activities.</td>
</tr>
<tr>
<td><strong>Strategy</strong></td>
<td>Size: Class size is an educational tool that describes the average number of students in each educational space [30]. The average amount of educational space per person is 1.5 to 2 square meters.</td>
<td></td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Specification</strong></td>
<td>The classroom, with dimensions 6.50 m * 8.00 m, occupies 12 students.</td>
<td>The classroom, with dimensions 6.50 m * 8.00 m, occupies 8 students.</td>
</tr>
</tbody>
</table>

NOTE: a small number of students inside a classroom is much better than a large amount to facilitate the interactions between the children and the teachers and to avoid distractions and discomfort [31].

4.5 Learning Space Discomfort

The environmental factors elements of ventilation, lighting, insulation, and acoustics may cause physical and psychological discomfort inside a classroom for children with CI that affects their performance and behaviors. Table 5 shows how the design of the classrooms may cause a learning space discomfort [16].
4.6 Autism

Acoustics is one of the aspects that has the most significant influence on autistic students' learning performance [20]. Table 6 shows how insulation and acoustics design impact children with CI.

Table 5 The impact of ventilation and lighting in a classroom on children with CI. (source: authors).

| Ventilation: An essential prerequisite for mental health and subjective well-being is clean air [5]. The higher ventilation rate may greatly enhance kids' ability to study. |
|---|---|
| Child Nature | Healthy Child | CI Child |
| Design | | |
| Specification | The windows from the north side allow natural ventilation and refresh the classroom air. | The windows from the north side allow natural ventilation and refresh the classroom air. |
| Strategy | Lighting: Despite the fact that the two types of lighting can be combined to provide adequate lighting for a variety of tasks in architectural spaces, it has been found that natural lighting is preferable to artificial lighting in settings like classrooms due to the psychological and physiological advantages it offers students. [19]. |
| Design | | |
| Specification | Natural lighting is essential in any educational space. | Artificial lighting should only be used when absolutely necessary. |

Table 6 The impact of classroom insulation and acoustics on autistic children with CI. (source: authors).

| Insulation and Acoustics: educational spaces must be insulated (walls and floors) to avoid noise and disturbance that may cause cognitive difficulties. |
|---|---|
| Child Nature | Healthy Child | CI Child |
5 Case Studies

5.1 Nida for Deaf and Hearing Weakness Rehabilitation

As Fig. 3 shows, Nida is a rehabilitation center for deaf and hard-of-hearing children in Cairo, Egypt. The school accepts students from two to six years old, teaching them different learning skills and rehabilitating them to integrate into normal life for the Primary Stage in School. The selection has determined the optimum design for a classroom that students with CI inhabit as a case study nationwide to distinguish between classroom design factors.

Figure 3 Design elements used at Nida Rehabilitation Classrooms
5.2 Maryland School for Deaf

The Maryland School for the Deaf is a multicultural, bicultural community that offers an equal and exceptional education in a supportive, stimulating, and demanding atmosphere to guarantee students achieve personal excellence and develop into responsible lifelong learners. By providing instructional, developmental, and extracurricular activities, the school helps students improve their intellectual and social skills, as shown in Fig.4. Two campuses exist at the school: one in Frederick and one in Columbia. Deaf and hard-of-hearing students can enroll at the Frederick Campus from kindergarten through grade 12.

![Image of Maryland School for Deaf Classrooms]

Figure 4 Design elements used at Maryland School for Deaf Classrooms

6. Classification of Elements in Rehabilitation Centers

Students with visual impairments (CI) require clear visual accommodations to access the curriculum and language in the educational environment. They must maintain visual attention to teachers, translators, and peers to promote comprehension. These accommodations reduce the need for students to split their focus between...
instructors, peers, handouts, and slides [8]. Classroom elements, as shown in fig. 5 and 6, are divided based on placement, with walls having 50% importance, floors having 20%, and ceilings having 30% importance. Specialists in the CI field prepare questionnaires to identify sub-elements scores within a classroom.

7. **Questionnaire Survey**

The questionnaire includes 48 questions divided into three categories (wall, floor, and ceiling). Each question was given a score according to its importance depending on the three classifications of design, making a 100% score. 31 persons, 6 Children Audiology Doctors, 8 Communication Specialists, 5 Sound Engineers, 7 Children Neurology and Psychology Doctors, 5 Teachers, answered the questionnaire. The results show that each element has a particular percentage of importance inside a rehabilitation classroom for children with CI. The answers varied, but all ranged in high scores with a slight difference according to the respondents' points of view. Fig. 7, 8, and 9 show the summary of the responses and statistics.
8. Results and Discussion

Previous research on students with intellectual disabilities primarily focused on physical and psychological aspects, leaving it challenging to find relevant references. Therefore, our study aimed to gather relevant material from references in architecture and medicine. Table 7 provides the study findings as a design checklist for a classroom designed for children with CI using architectural techniques. The checklist, based on studies, questionnaires, field visits, and children's behaviors, consists of floors, ceilings, and walls. It aims to create a healthy, conducive environment for learning and development, ensuring a conducive environment for children with CI. *(according to the British Code for deaf Children and hard of hearing)*

Table 7 Design checklist

<table>
<thead>
<tr>
<th>Items</th>
<th>Percentage</th>
<th>Specification</th>
<th>Over design 0%</th>
<th>Optimum 50%</th>
<th>Sub-optimum 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>Space Design</td>
<td>6%</td>
<td>The combined Activity and Withdrawal spaces must provide a minimum of 3.25 m(^2) of unoccupied space per child.</td>
<td>0-2.0m(^2)</td>
<td>2.0 m(^2) – 3.0m(^2)</td>
</tr>
<tr>
<td></td>
<td>Orientation</td>
<td></td>
<td><em>Orienteion:</em> The main aspect of orientation is to maintain sunlight and cool natural air inside a classroom in the northeastern direction.</td>
<td>South East /South West</td>
<td>North West</td>
</tr>
<tr>
<td>Fixtures and Furniture</td>
<td>6%</td>
<td>Benches: At least one bench must be high enough to accommodate wheelchair access and must be 0.60m high for children ages 0 to 4 years and 0.72m high for children ages 5-8 years.</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>1%</td>
<td><strong>Cabinet</strong> surfaces are made of durable, low-maintenance laminate, including lockable cabinets for all objects stored inside a classroom. <strong>Bag Storages:</strong> Pigeon hole joinery units with dimensions of 0.30 m wide by 0.30m high and a maximum height of 1.00m. Bag hangers with covering shelves may also be used if they are within close proximity of the activity area. An option is hooks, which must have protective wood coatings. The section with the children's restrooms is not where the bag storage space should be.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation: According to the space function, it is the orientation of the furniture. Flexible moving furniture must be provided for different activities and purposes inside a classroom. <strong>Textures:</strong> avoid rough and sharp textures for the safety of the children.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Floorings</strong></td>
<td><strong>Use anti-slippery materials such as rugs, vinyl, carpets, and foam mats that must strike a balance between having some patterning and not being overly light in color (simple cleaning and a reduction in markings showing), as well as in relaxing colors and patterns for kids with severe sensory difficulties. The floor treatments should improve the acoustic qualities of each space.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Restrooms</strong></td>
<td>• At least two restrooms are available with direct access from and to the classroom. • The restroom door width is between 0.80m to 1.00m for wheelchair access • Restrooms include a toilet, a sink, and a shower space.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Ceiling** | **Acoustics**

Floors and wall insulation inside a classroom are used to reduce background noise either from outdoors or indoors. Use acoustics wall panels to avoid reflecting noise back to the children with CI. **NOTE:** The cochlear implant audiologist can consult with the education staff to provide specific advice for limiting or preventing static electricity exposure in the classroom. High static electricity levels can harm the cochlear implant's internal and exterior devices, reducing its effectiveness. |

<table>
<thead>
<tr>
<th><strong>Ventilation</strong></th>
<th><strong>Artificial Ventilation:</strong> Air conditioning or heater adjusted with temperature between 23°C to 25°C.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Height and Structure</strong></td>
<td>• Clear space without columns or structural elements. • Flat walls and ceiling to avoid echoing and noise reflections on children with CI. • Clear ceiling height is between 3.0m to 3.5 m to give the children a sense of comfort and safety.</td>
</tr>
<tr>
<td>Lighting</td>
<td>5%</td>
</tr>
<tr>
<td>Types of Ceiling</td>
<td>2%</td>
</tr>
<tr>
<td>Wall</td>
<td></td>
</tr>
<tr>
<td>Boards, smart Boars, Projectors</td>
<td>9%</td>
</tr>
</tbody>
</table>
| Doors | 8% | - The door width is between 1.00m to 1.20m and height of 2.20m
- Doors adhere to accessibility requirements.
- Viewing panels installed between 0.80m and 1.80m above the floor for visibility and monitoring.
- Fully glazed doors are used in situations where full height visibility from the inside to the outside is required and must have a mid-rail that is between 0.90m and 1.00m above the floor. | Width >1.0m / <1.2m | Width 0.9m-1.3m | Width 1.0m - 1.2m |
| Charts and Display Boards | 6% | Charts: not more than 2 charts with cool colors. | <2 charts | / | >2 charts |
| Colors | 15% | Colors: avoid warm colors; instead, use cool colors for furniture and walls. Use matte rather than gloss paint on walls to reduce glare. | Warm Colors | / | Cool colors |
| Windows | 4% | Natural Lighting: windows of 30% of the room’s total area with external sunscreens as slat or roller sunscreen. | 0-10% | 10-25% | 30% |
| 4% | Natural Ventilation: classrooms are naturally ventilated, offering openable windows or openings, each with a width of 1.0m to 1.5m. Windows openable surface is approximately 10% of the gross surface. | 0-5% openable | 5%-10% openable | 10% openable |
| Alarm signs and signals | 4% | - A silent monitored security alarm system that combines smoke and movement detectors.
- Emergency signs are placed on top of the classroom’s door. (Exist Signs) | / | / | / |

9. Conclusions

Despite the understanding of rehabilitation space design guidelines, there is a shortage of research on the influence of RC classroom design on children with CI, which is identified as a research gap. The study investigated the architectural features of the design of the classroom for children with CI in an attempt to develop a model of
the ideal classroom based on architectural methodologies. The design checklist shows every architectural and design element in the perfect configuration inside the classroom for kids with cognitive impairments. Thus, as the hypothesis suggests, there are significant architectural approaches that affect the design and arrangement of classrooms for children with CI in rehabilitation facilities.

The checklist concludes each design element that must be available within a classroom with an accuracy of 100% for the sub-optimum, 50% for the optimum, and 0% for the over-design on the checklist. Therefore, designers aiming to create a successful and healthy environment for the CI children may benefit from the checklist by implementing it to assist in satisfying the children’s demands and requirements in the most optimal way possible.

List of Abbreviations
CI – Cochlear Implant          RC – Rehabilitation Center

Ethics approval and consent to participate
This research did not require Institutional Review Board or Committee approval because the questionnaire held does not report individual cases or case series, rather, it analyzes the importance of each element of design inside a classroom for CI children according to each participant’s point of view. The participants approved their participation in the survey without any compensation.

Consent for publication
Not Applicable

DECLARATIONS
Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests
The authors declare that they have no competing interests.
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Not Applicable

Authors' contributions
ES analyzed the theoretical section regarding the CI and the habilitating process. TR performed the questionnaire for the classifications of design elements. YS contributed to designing the checklist and writing the manuscript. All authors read and approved the final manuscript.

Acknowledgments
Not Applicable

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