

ORIGINAL ARTICLE



L-Ball: Designing A Novel Sports Electronic Audio Ball for Visual Impairment Student

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ABSTRACT

Background. A field study conducted by researchers found the balls used by visual impairment students at school basically used the sound by a small bell inside the ball. However, the sound emitted from the ball is very limited, the ball will sound when it is moved. This makes it difficult for students with visual impairments to find a missing ball that not emitted makes a sound. **Objectives.** A Loud-ball ("L-Ball") is a prototype ball designed by a researcher using an electronic circuit that produces non-stop sound intensity during play. This study focuses on prototype design by considering the selection of mechanically strong lightweight electronic components, such as batteries and buzzers. **Methods.** The L-ball prototype design uses the main electronic components is a lithium battery and piezoelectric buzzer. Then, the sound intensity measured at different distances by the researchers for the ability of electronic components to emit sound from inside the ball. Impact measurements are also carried out to ensure that the electronic components inside the ball do not dislodge during the use of the ball. **Results.** The results showed that the maximum L-Ball sound intensity emitted was 64 dB with impact resistance performed 100 times. Finally, the sound emitted is suitable for playing fields with a width of 3 meters and a length of 13.4 meters. **Conclusion.** L-ball is designed like a ball for visual impairment, the quiet of the stadium is the main requirement the L-ball sound can be heard optimally by all players.

KEYWORDS: *Visual Impairment, Audible, Sports, Balls, Design.*

INTRODUCTION

Sport is an inherent, low-cost way of encouraging dynamic and spatial training for disabled persons (1). It increases community social boundaries and diversity with higher participation (2). Compared to their peers with normal vision, visually impaired children urgently need sports activities (3). This is because visual impairment limits their involvement in play, which noticeably delays their physical development (4). Several electronic vision aids have been developed. However, most are designed to improve mobility skills for the visually impaired, including robotic devices, such as sensor blind stick, and distance measuring glasses (5, 6).

Tools to help the visually impaired participate in sports are currently limited. A sports aid, such as a sound ball with embedded bells, has been developed in the previous research, though it has drawbacks. For instance, the bell protrudes against the surface of the ball, affecting the direction of its rotation. Additionally, this bell only sounds when the ball is in motion or is being used. Therefore, an electronic audio device is an alternative material implanted into the ball. The device emits a sound; hence ball's position can be easily detected by the visual impairment.

Besides, one solution in team sports that is more accessible to visually impaired people is

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Goalball. In 2013, Goalball came to Indonesia and officially became a sport that was competed in the Paralympics Olympics, and at the 2018 Asian Para Games. It has become a new competition in Indonesia, and, until now, Goalball is one of the most popular sports for visually impaired people.

Goalball is a game specifically for the blind or visually impaired athletes wearing an eye patch. This sport consists of two teams, each with 3 players, standing before their goal during the match. The ball thrown by the opponent may be blocked by the body to prevent scoring a goal. Since the players are visually impaired, the ball is embedded with a bell that jingles when the ball rolls. That is why those participating in the match must remain silent for players to concentrate on hearing the ball's direction (7-9).

Although Goalball solves the accessibility problem of sports games for the visually impaired, several areas still need improvement. This sport provides an enjoyable experience for athletes with visual impairments (10). However, Goalball and its rules should be developed into a game that is suitable for athletes, the blind people in the community, as well as in the school environment.

Goalball still has several limitations, such as cost, mobility, and setup. A ball embedded with a bell inside is categorized as a piece of expensive competitive equipment. The sound of the ball is only heard when the ball is in motion. Moreover, a visually impaired person only plays Goalball in special arenas, such as a very smooth surface. This limits the mobility of players that cannot use other courses. Apart from that, this game requires the help of normal people to pick up and give the ball to the player when it is not moving. In this case, the match referee must move the ball to produce sound. The player then comes over and takes the ball.

For people with visual impairments, communication should be performed using alternative channels (11, 12). Visually impaired people are often thought to have better hearing. Although there is no evidence to support this idea, listening becomes an alternative for communication (13). The sense of hearing helps understand the environment and detect invisible objects (14). Using hearing to detect location is applied in playing sports, such as Goalball. For

the visually impaired, the sound is important in indicating the ball's location, and avoiding possible accidents (15). However, the jingling of the bells embedded in the ball is only heard when the ball is in motion. When the ball is static, blind people experience confusion in detecting its location. Moreover, the use of a wide playing field dimension requires physically fit players. The relatively high price of Goalball makes the game less friendly for school settings, such as during physical education lessons in special schools.

Besides, one solution for visually impaired children to participate in sports activities is using a special ball that makes a sound. The introduction of a sound ball for visually impaired people helps them access more lifelong physical activity opportunities. For instance, the creation of a sound ball in tennis has paved the way for visually impaired individuals to successfully participate with other students in physical education learning (16). In America, the sound ball was introduced in 1964 through beep baseball, which is played by blind or low-vision people (17). The previous research showed that the use of sound balls in baseball games allows blind children to fully participate in mastering their favorite sports (18). However, this game is still considered to be costly in procuring equipment. Another alternative is creating the I-ball, referred to as programmable sound ball (19). However, the I-ball ball is still considered complicated to make because it requires experts in building its programming system.

This paper presents a preliminary test on the operation and performance of an innovative sound ball design and play, called the Loud Ball or L-Ball. The L-Ball is made by utilizing electronic audio to help blind players use their sense of hearing to detect the location of moving objects. This game reduces dependence on normal people and provides access to safer and less tiring sports activities. L-ball is designed based on principles of safety, the use of ball material, choosing the color of the ball that suits personal needs, and the affordability of manufacturing costs. Furthermore, the L-ball is advantageous over the existing sound ball because it is rechargeable and makes sound continuously even when the ball is stationary. In conclusion, the paper makes some considerations

on current designs and areas for future work from an accessibility perspective.

Loud Ball (L-Ball). Loud ball is an electronic audio ball that sounds continuously, making its position easily detected by the visually impaired. This sport is played by adapting to the goalball game. Due to the school setting's needs, several factors have been modified, including the playing field, equipment, number of players, and other rules suitable for blind students. In this research loud ball (L-ball) refer to innovations in the ball and field.

The rules of the loud ball (L-Ball) game are, briefly:

The playing field dimensions are 13.4 m × 3 m, while the goalposts are 1.3 m high and 3 meters long.

One team comprises 3 main and 3 substitute players. The lines between the players is 1.9 meters, marked by a 5 cm wide adhesive tape. The line should be easily detected by the player's hands and feet.

The objective of the game is to roll a ball weighing 0.6 kg and 0.22 m in diameter. The ball has an electronic sound component and a 1 cm diameter hole, which emits sound. Also, to enhance hearing silence during the game is critical.

The ball is rolled over the goal line to score. All players wear an eye patch during the game. The ball is rolled back and forth using hands to score and avoid own goals. Each player is only allowed to move within the vertical lines.

Throws on goals are allowed from 1.9 m between the lines where the players are standing. The defense is allowed within 1.9 m from the goal line.

The game is played in two rounds, each 300 seconds. It is dynamic and requires absolute spatial mobility, sound localization, and good physical fitness.

This game is officiated the main referee, two goal-line referees, and one time-keeper.

Every fault committed by individuals or teams, results in a penalty. Individual faults

include not rolling the ball when passing, the player crossing the designated line, the ball not being passed for more than 10 seconds, and making the initial throw before a referee's signal. The team's faults include making noise and controlling the ball for more than 10 seconds.

The coach or substitute player cannot give instructions during the game. However, they provide instructions during breaks or half-time changes.

Some of the challenges in the low-vision person game include:

- The sound balls used by blind students generally come from bells or sand. This makes it difficult for students to detect the ball's location when it is not in motion.
- Blind students always need a person with normal eyesight to pick up the ball that is not in motion. This reduces student independence.
- Team games for visually impaired students are still limited.
- The existing team games use expensive tools and equipment.

MATERIAL AND METHODS

A loud ball (or L-Ball) is originally made by researcher is developed as an alternative ball based on electronic audio to help visually impaired students play sports. [Table 1](#) shows the materials and equipment used to develop the L-Ball. Polyurethane (PU) microfiber synthetic leather ball was used as the main material in designing the L-Ball. The ball was selected due to its high flexibility, durability, and resistance to weathering, water, or chemical substances (20). It has a synthetic rubber bladder that holds air pressure inside the ball. The material also protects the ball and keeps the air (21). The ball is composed of 12 hand-stitched pentagonal panels. Since the L-Ball uses an electronic system circuit, it provides rich and various interactions. This way, it allows the beep sounds emitted by a buzzer continuously even when the ball is motionless.

Table 1. Materials and Equipment in Designing L-Ball

No	Materials and Equipment	Specifications
1	Ball	Materials: Polyurethane (PU) microfiber synthetic leather; $\varnothing = 8.5\text{-}9$ inch / 22-22.5 cm; Ball mass: 14-16 ounce or 0.40 – 0.45 kg; Technique: hand-stitched
2	Piezoelectric Buzzer	White; $\varnothing = 23$ mm; Cable length = 100 mm; Sound level = 85-95 dB; Voltage range = 3 V– 4 V, max 10 mA
3	Battery	Type = polymer; Length = 35 mm; Width = 20 mm; V = 3.7 volt; Capacity = 620 mAh
4	DC Connector	$\varnothing = 5.5$ mm; Massa = 3 gram; Height = 2.1 mm; A = 0.5 A; VDC = 50 vdc

The L-Ball was assembled to plant the electronic audio circuit that produces sounds from the piezoelectric buzzer, battery, and power connector. The circuit was assembled using soldering iron. It is attached to the ball's inner panel and protected by thin sponges. The ball was then coated by foam and inner tubes for increased softness and weight to roll. The next stage was ball hand-stitching by professionals and ball pumping. Before measuring the sound, level emitted from the buzzer, the sound level meter applications were tested for validity and calibration. This was to ensure that the applications were valid and reliable in measuring the sound level. The applications include DecibelX, Nios Sound Level Meter, and Soundlog Noise Dosimeter. The validity and

calibration test results were then compared to the standard measurements and selected for the field test. The ball material was tested using a ball thrower, placed horizontally 10 meters from the wall. The ball was bounced 100 times to test the resistance impact of the audio circuit inside.

RESULTS

The L-Ball has been developed to assist visually impaired individuals when playing sports. This hand-stitched ball is made of leather and embedded with a piezoelectric buzzer that emits sound from an electronic audio circuit, as seen in [Figure 1](#). The continuously emitted sound allows the L-Ball to have a richer and more varied interaction. This assists visually impaired individuals to hear the sound.

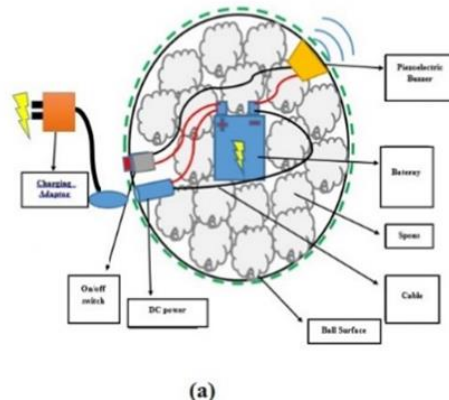


Figure 1. (a) L-Ball Embedded. It Is an Electronic Audio Circuit, a Rechargeable Battery, and a Buzzer Emitting Beep Sound (Inset: The Ball with Circuit Embedded). (b) L-Ball Product

Designing is conducted once the materials have been prepared. A hand-stitched ball was prepared, and a sound component was installed inside it. A 5.5-mm hole was made in one of the ball panels to attach the power connector. Parallel to the panel, a 2-mm hole was made on the other panel for the buzzer sound to be easily heard. Inside the ball, the audio electronic circuit was covered by thin pentagon-shaped sponges. The sponges protect the circuit from collisions or tensions. The next step was inserted into the bladder, which holds air. The ball panels were then hand-stitched. Therefore, the ball could be inflated up to 40-60 kg/m and used with the sound on or off.

One of the most important parts of the L-Ball is the audio electronic circuit. The circuit was assembled by connecting the wires in the piezo buzzer, the power connector, and the battery. The negative wire in the piezo is connected to the negative pole 1 in the power connector. Similarly, the battery's

negative terminal is connected to the negative pole 2 in the power connector. The piezo's positive wire is connected to the positive terminal of the battery and in the power connector. The piezo buzzer produces sound when the components are appropriately connected. This circuit was then adhered to the inner part of the L-Ball panel. [Figure 2](#) shows the audio electronic circuit that has been assembled.

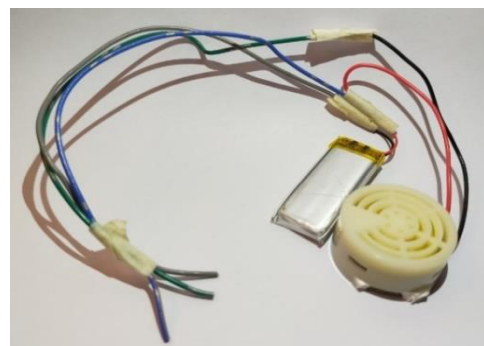


Figure 2. Electronic Audio Circuit

Another important component is a 620mAh lithium battery that powers the electronic audio circuit. The rechargeable battery was connected to 5-volt piezo buzzer and on/off lever. The battery is recharged using a DC power connector. The connector functions as an input to flow the electricity from the charger adaptor using a DC jack and socket. The push-pull lever must be pulled and pushed to switch the circuit on and off, respectively. The L-Ball produces continuous sound for 10 hours. As part of the calibration procedure, the sound level emitted from the audio circuit must be measured. In this study, the sound level was tested in a court and measured using some applications of sound level meters.

Figure 3 shows the results of calibration measurement using sound level meters. The sound level of L-Ball was measured by 3 applications, including DecibelX, Nios, and Soundlog. The applications measure the sound level of 30-130 Db, and the frequency level of 20-20.000 Hz. The testing

was performed 16 times outdoors in the afternoon time with the environmental noise level of 30-40dB. The performance of each application is assessed based on stability and accuracy. Figure 3 shows the calibration results among the 3 applications. The results show the fluctuations in sound level among the applications. The highest measurement point is shown by DecibelX application (point 2 = 64dB) and Soundlog (point 5 = 56dB). Moreover, Figure 3 indicates that the DecibelX application shows a higher sound level with a more stable measurement. The percentages of accuracy level among DecibelX, Nios, and Soundlog were 54.71%, 46.56%, and 45.19%, respectively. This indicated that DecibelX had the highest accuracy of all applications. Hence, DecibelX was used to measure the sound level of the L-Ball.

The sound emitted from the L-Ball was then tested in the field using DecibelX. This test was to determine the feasibility and dimensions of the L-ball playing field. It was aimed to ensure that all players could hear the L-Ball sound.

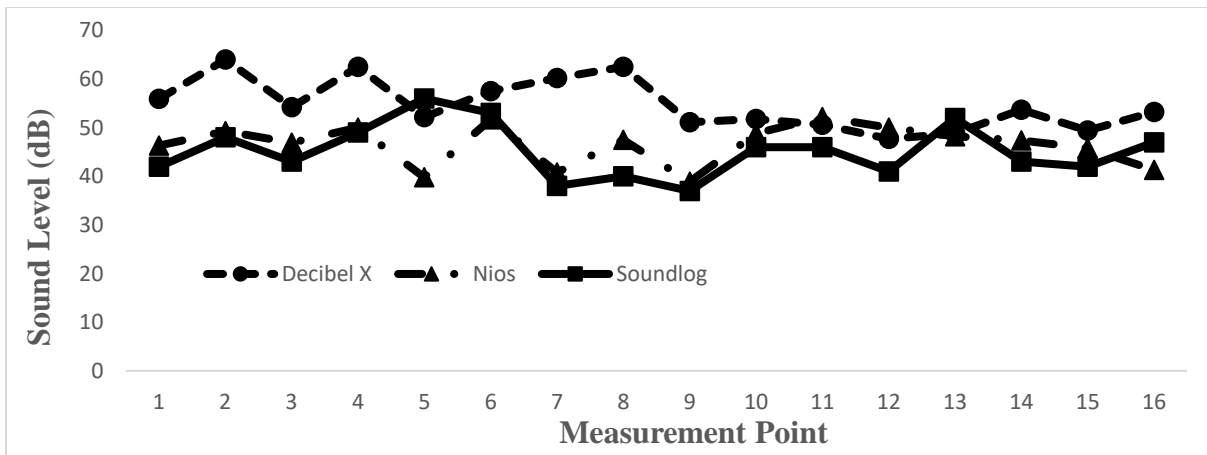


Figure 3. Results of the Calibration Procedure of L-Ball

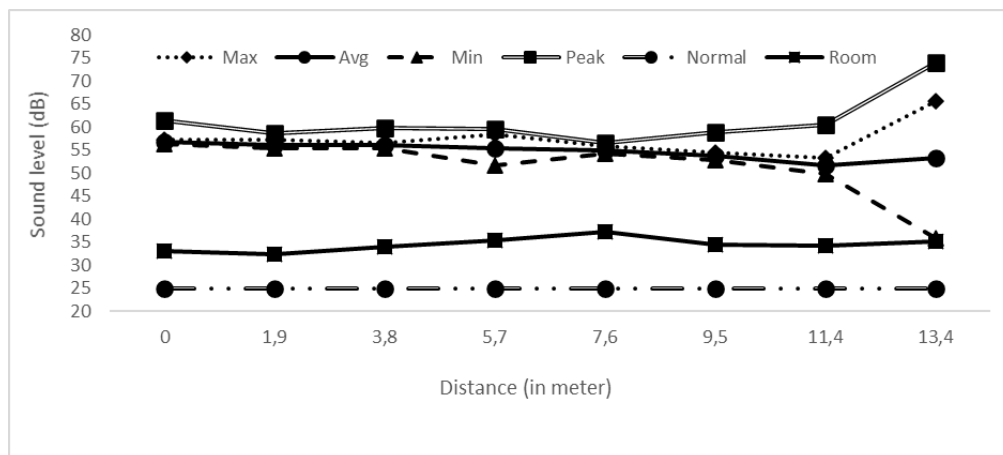


Figure 4. Results of L-Ball Field Testing

Figure 4 shows the results of sound level measurement in L-Ball play. The test was based on the relationship between the average levels of normal hearing of the visually impaired players, the level of room noise is 25 dB, and the average room noise is 34.51 Db. The average ball sound heard by all players is 55 dB when the ball is at a distance of 7.6 meters from the player's standing position. At a distance of 0 meters, the ball's maximum sound is 57.41 dB, while at a distance of 11.4 meters, the ball sound heard by the player is 49.9 dB. The L-ball's minimum sound emission (49.9 dB) is still greater than the normal hearing average (25 dB). This means that the dimensions of the L-ball court area of 13.4 x 3 meters are suitable to be used as the official L-ball playing field.

DISCUSSION

The design process of L-Ball conforms to the procedure of designing learning media for visually impaired students. The L-Ball is designed to pass the criteria of performance testing in some aspects, including ergonomic performance, electronic circuit function, materials used, physical characteristics, and the ball's color. The ergonomic aspects of the ball are assessed to minimize health and safety risks. The ball should be safe, practical, and comfortable for use by visually impaired students. The sound level should be appropriate to be heard by the users. As a result, the L-Ball was created with 12 pentagonal panels, with a ball diameter of 8.5 inches and mass ranging from 14-16 ounces.

An analysis has been conducted to obtain a good and efficient L-Ball system, which includes the sound-producing electronic circuit from a piezoelectric buzzer, battery, and power connector (Figure 2). The poles' placement on the piezoelectric buzzer cables, battery, and power connector must match when making the electronic circuit. The electronic audio circuit was connected using lead heated with a soldering iron. To avoid short-circuiting, each cable connection was wrapped with an insulator. The electronic audio circuit was then attached to the inside of the spherical panel and was protected by a thin sponge for impact resistance. In the finishing process, the L-Ball for the blind was hand-stitched by skilled personnel at a ball making company.

The L-Ball material must be strong, lightweight, and safe for visually impaired children. Therefore, it is designed from a ball with

an outer layer made from synthetic leather polyetherane (PU) material. The PU material was chosen because it has flexible characteristics and highly resistant to weathering, water, and chemical fluids (20). The inner layer or bladder of the L-Ball is made of synthetic rubber. This bladder serves to hold the stability of the air pressure inside the ball. Also, the synthetic rubber material makes the ball durable and airtight (21).

For electronic audio material, the L-Ball uses a piezoelectric buzzer or an electric buzzer. This is an electronic component that converts electrical signals into sound vibrations (22). Piezoelectric was discovered by Pierre Curie in 1880. After World War I, the piezoelectric began to be used for applications in underwater object detection sonar (23). The piezoelectric buzzer embedded in the L-Ball works to produce sound from inside the ball. It is circular, white with a diameter of 23 mm, and a height of 12 cm. This buzzer produces a sound between 85-95 dB in electric pressure of 12 V DC. It works well in the voltage range between 3-4 V, a maximum of 10 mA. There are cables with positive poles (red) and negative poles (black) as a medium to conduct electric current.

The L-Ball also uses batteries to store and provide DC power, consisting of one or more cells connected in series (24). This lithium battery type was chosen because it is liquid and uses polymer electrolytes that deliver power faster (25). The lithium battery in the L-Ball is rechargeable. This rectangular battery with a length of 35 mm, a width of 20 mm, and 10 grams, stores a maximum electrical charge of 620 mAh. The battery is able to work on devices with a maximum voltage of 3.7 volts. This lithium battery type is environmentally friendly, flexible, safe, and lightweight, but with a short life span (26).

The L-Ball also has a power connector, which receives and supplies power to the ball's batteries. The connector uses a low-voltage DC with current and voltage levels determined by the manufacturer. The DC power connector is circular with an inner pin diameter of 2 mm, an outer sleeve diameter of 5.5 mm, 3 grams, and a height of 2.1 mm. This connector works at 12 V DC voltage, 1 ampere, and 100M Ω , 500V DC isolation resistance.

The shape of the L-Ball is analyzed to obtain a sound ball product suitable for visually impaired children. Therefore, the shape of the L-Ball must

be simple and safe. The simplicity means that the product's structure should not be complicated, and must be easily recognizable. Furthermore, the ball must be made of harmless material. Therefore, for simplicity and safety, the L-Ball has a symmetrical round shape. The entire surface of the L-Ball has a yellow color to help children with visual impairments. Color has a relationship to a person's general impression of something, and yellow evokes cheerfulness, inspiration, and pleasantness. Also, the yellow color gives a bright impression on blind children in the low vision category (27).

To analyze the L-Ball's accuracy and feasibility, several Sound Level Meter (SLM) smartphone applications were used to monitor the ball's sound intensity when used in the field. According to the American National Standards Institute (ANSI), there are two main types of sound level meters (SLM), which are Class 1 and Class 2 (28). This study employed Class 2 SLM, which is generally used for measuring sound level in the field. According to ANSI (2013), the total error allowed for SLM noise measurement at frequencies between 20 Hz and 20 kHz, is +3 dB to +5, -1 dB for Class 2 instruments (28).

Several studies have explored the accuracy of SLM smartphone applications to assess sound level exposure. Certain applications on iOS devices may be considered accurate, reliable (29) and perform better (30). The accuracy of iOS smart devices in measuring sound level exposure, various types of microphones and iOS devices were used to measure noise ranging from 60-100 dBA, from the applications tested, and none was accurate enough to be used without calibration due to nonlinear errors and different sound levels (31). Therefore, this study only used the iOS-based SLM application as a calibration procedure to determine the accuracy of SLM application in L-Ball in the playing field. The 3 smartphone applications, Soundlog, DecibelX, and Nios - were used to measure the ball's sound level. The distances between sound ball and applications are arranged in a way that represents the spectrum produced in measurements with 48 tests.

The application on the iOS platform used in the research was DecibelX. It works well with an average difference of -0.7 ± 2.1 dB in all distances between application placement and the sound ball. The results for the DecibelX application correspond to the total range of allowable errors found in ANSI S1.4-2014. These results show

that DecibelX has the best potential of the application tested for use by ordinary people to determine sound levels and the environment for filtering purposes. Furthermore, the DecibelX application has the potential to be used as a screening tool in this research scenario because consistency at all distances, sound levels, and errors are very low.

Two factors affect the measurement of sound levels. The factors make the sound measured using the SLM application inaccurate or different from the actual sound level. These factors are varying wind speed and the measurement position. To minimize measurement error in this study, the surrounding environment's sound is measured before adding the ball sound during the calibration of the sound level meter application.

CONCLUSION

As part of the dissertation research, L-Ball was introduced as an adaptive sports aid that transmits sound based on electronic audio circuits. It aims to help visual impairment participate properly in team sports activities. During use in the L-Ball game, the maximum sound intensity heard is 51.49 Db and functions optimally within a radius of 6.65 meters, meaning that with the dimensions of the L-ball field of 3 meters x 13.4 meters, the sound of a emitted from ball can heard by all player. In addition, the findings indicate that the weather conditions outside the field affect the intensity level of the ball sound heard by the players. The use of a sports building roof made of zincaluminum has increased indoor field noise by up to 60 dB during heavy rain. This certainly affects the intensity level of the ball sound heard by players on the field. Therefore, environmental noise is a major concern in L-ball games. L-ball impact testing has been performed, resulting in 100 times the impact resistance. The L-ball prototype design is only at the stage of define, design and development. It is suggested for future research that the L-ball prototype should to be disseminated directly to visual impairments.

APPLICABLE REMARKS

- The design of the L-ball prototype as yet in the defining, designing, and developing stages. To determine the level of use of the L-ball for visual impairment users, the process of dissemination to users is necessary for future research.
- The global Covid-19 pandemic limits this research to the dissemination process to users, but the dissemination process will still be carried

out by researchers with the consideration that after the Covid-19 pandemic ends or

dissemination with the Covid-19 health protocol.

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