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# Development of Modified VO2Max Test Instrument

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## Abstract

The endurance component, namely VO2Max, is the part of physical fitness that supports important conditions. In terms of physical fitness, especially endurance, there is a need to develop test equipment to support and improve the performance requiring VO2Max. This research was aimed to develop an instrument prototype, namely the Modified VO2Max Test, using Ultrasonic sensor with lamp (LED 3 x 3 12VDC) and Buzzer (Piezzo 3-12 VDC). The set of this instrument consisted of four slaves. The placement of each LED sub-device depended on the need of the user. The basic circuit included sensors, WiFi modules, RGB LEDs, and a doorbell. The function of the sensor was to detect objects in the sensor area. The RGB LEDs acted as a signal when the sensor received stimuli. In addition, this instrument was made to facilitate the user movement in adding their skills according to their blindness. The valid test results showed an (rxy) value of 0.886. Compared to the table of r = 0.282, the value of rxy was higher with a sig value of 0.000<0.6. It concludes that the modified VO2Max test is reliable. This VO2Max Futsal Prototype product is useful for players to examine their VO2Max and physical fitness.

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## INTRODUCTION

Science and technology are currently developing rapidly, starting from changes in human thinking to the development of devices providing comfort in doing activities. Technological development, especially in the field of sports, is an integral part for improving an athlete performance; whereas, in this century, sports require speed, good endurance, high intensity, and concentration (González-Espinosa, 2020; Lizaur-Utilla et al., 2019). Technological advances, especially in sports, are integral parts for improving the performance of athletes in this century. The physical fitness of a soccer player requires complex movement skills and abilities, such as sprinting, jumping, turning, and stepping without losing balance. The result of the transfer process is fatigue, which directly affects the work of the heart, lungs, circulatory system, respiratory system, muscles, and joints. Therefore, players must be in a good physical shape to maintain their performance during the game. Futsal is a game requiring good physical fitness. In this game, players keep focusing on hitting opponent targets to get maximum points. Considering the short movement time, that is less than a second, futsal athletes must perform a defense on the playing field and have a high concentration to make decisions and respond quickly and accurately to stimuli during the game (Mahadzir et al., 2019; Oliveira, 2021)

Modification of VO2Max test device refers to the use of modified devices and technologies to measure or estimate a person VO2Max value. VO2Max is a measurement of a person maximum capacity to consume oxygen while exercising to the maximum level. The VO2Max test is generally performed using a device called a spirometer that measures the volume of oxygen inhaled and the volume of carbon dioxide released by the subject during physical activity.

Modifications of VO2Max devices can cover various aspects, including hardware and software components. Some common modifications include the use of more advanced sensors. VO2Max devices can be modified by replacing or upgrading sensors used to measure the flow of oxygen and carbon dioxide. A more accurate or responsive sensor can provide more accurate data on the volume of oxygen consumed and the volume of carbon dioxide produced by the subject (Hebisz et al., 2016; Pelana et al., 2020; Stevens, 2016). Modifications can also include the integration of monitoring technology. Modifications may involve the integration of other monitoring technologies, such as heart rate monitoring, body temperature monitoring, or muscle activity monitoring. This additional data can provide a more complete insight into the body response during a VO2Max test.

Another form of modification is the modification in analysis software. Modifications can involve the development of specialized software or computer programs that process data from VO2Max devices. The software can provide a more detailed analysis of breathing patterns, activity intensity, or VO2Max estimates based on the data obtained. The next modification is on the increased comfort and safety. Modifications can also be made to improve the comfort of subjects undergoing VO2Max tests. For example, the design of the device can be modified to be more ergonomic or lightweight, so that the subject can perform physical activity easier. In addition, safety measures can also be enhanced to minimize the risk of injury or discomfort that may occur during the test (Blom, 2020; Brake, 2020; Pinto, 2021; Svensson, 2020). It is important to note that the modification of VO2Max devices should be carried out carefully and in a controlled environment. Accurate and consistent results are essential in the use of VO2Max tests to evaluate an athlete physical condition and performance (Bueno, 2020; Castro, 2022; Oliveira, 2021; Reis et al., 2023).

Elements involving cognitive processing speed, motor speed, and motor ability to anticipate the opponent shot are basically needed by professional players. On the other hand, the results of another study show that the characteristics required for the maximum speed of the ball direction are speed, agility, high intensity, and the ability to concentrate. In addition, the coordination of sensory nerve and motor nerve stimulation is important in this sports game. One of the indicators of coordination is the reaction and flexibility to respond quickly and accurately to stimuli. The tool produced was a modified tool of the beep test for athletes. The innovation apparent in this study is the improvement of VO2Max andro lights and sensors. In some good conditions, it can improve one of human physical abilities as the most important determinants of performance. Agility is created by explosive power movement. The amount of force is determined by the contraction of muscle fibers. The speed of the muscles depends on the

strength and contraction of the muscle fibers. The speed of muscle contraction depends on the adhesion strength of the muscle fiber and the transmission of nerve impulses. The created instrument must contain movements to change the position and direction of the body. The stimulation of the nerve center determines the success of physical fitness, considering that physical fitness is the primary physical ability (Peachey, 2020; Romero-Caballero, 2020).

Real movement characteristics of a futsal player involve structure of game duration and rest periods, heart rate, and lactate concentration produced after the game (Junior, 2022; Müller et al., 2018; Nascimento, 2021; Sumpena, 2021). The training structure should be organized effectively and efficiently based on the characteristics of the movements of the futsal player to support the performance of high-level players. The technology used in this research was an LED-based lamp with a Wi-Fi system module providing an automatic on-and-off signal when contacting with the racket during movement. In addition, the slave part was provided with a sensor, a clock, and ten small circular LED lights. These three components were the outputs of the Wi-Fi module. The technology developed in this research was the Modification of VO2Max Test instrument using Ultrasonic Sensor with Lamp (LED 3 x 3 12VDC) and Buzzer (Piezzo 3-12 VDC). This device is a wireless device that provides convenience to the user.

## METHODS

The development of this training media is related to the VO2Max Test Instrument Modification, including Ultrasonic Sensor with Lamp (LED 3 x 3 12VDC) and Buzzer (Piezzo 3-12 VDC) using several material components.

### Specifications

The device has eight specifications, including (1) Microcontroller: Atmega 328P, (2) Voltage: 3-12 VDC, (3) Sensor: Ultrasonic, (4) Lamp: LED 3 x 3 12VDC, (5) Buzzer: Piezzo 3-12 VDC, (6) Cable: AWG 24 4 pairs, (7) Connector: Jack CB8, and (8) Display: LED I2C 20x4.

### Complete Kit

The devices in the complete kit include (1) MST VO2Max Modification Test Device, (2) Panel Lamp Indicator, and (3) Connector Cable @12 meter - 1 Adaptor DC 12V 2A.

### Research Design

The research method used in this study was the research and development (R and D) method. This research method is used to produce certain products and to test the effectiveness of those products. The phases of the research product design is presented in Figure 1.

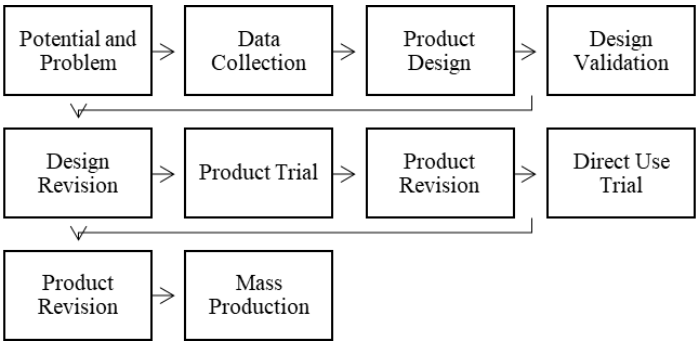


**Figure 1.** Research Stages and Process

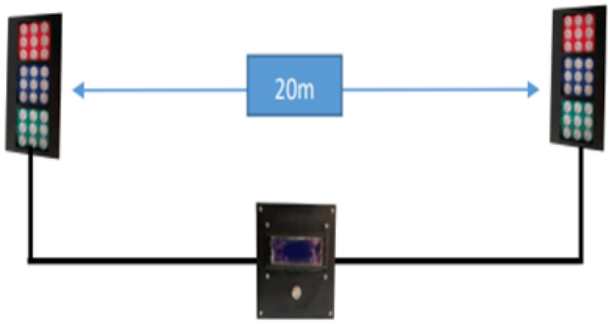


**Figure 2.** Modification of VO2Max Test

### Research Stages and Process

Figure 1 shows the design of VO2Max product. This endurance instrument device consists of Microcontroller (Atmega 328P), Voltage (3-12 VDC), Ultrasonic Sensor with Lamp (LED 3 x 3 12VDC), Buzzer (Piezzo 3-12 VDC), Cable (AWG 244 pairs), Connector (Jack CB8), and Display (LED I2C 20x4). Meanwhile, the comple kit of this device consisted of (1) MST VO2Max Test Modification Device, (2) Panel Lamp Indicator, and (3) Connector cable @ 12 meters - 1 DC Adapter 12V 2A. The system works when the power button is pressed and everything is connected between the device and the lamp marker panel 2. Second, the button only needs to be pressed once, not pressed and

held. Third, when it is activated, the light on the screen will light up and the system is ready for use. Fourth, the target remains in front of the sensor on the lamp detector panel. Fifth, wait until you hear a "BEEP" from the device or see the green light on the lamp display panel. Sixth, when the sound is heard and the lights are seen, the subject is welcome to run to the other lamp. Seventh, repeat this every time you hear the sound. Eighth, the test results are displayed directly on the screen of the device.

**Figure 3.** The Device (Microcontroller Atmega 328P) and Voltage (3-12 VDC Sensor)

Design specifications of this device include Microcontroller (Atmega 328P), Voltage (3-12 VDC), Sensor (Ultrasonic Lamp: LED 3 x 3 12VDC), Buzzer (Piezzo 3-12 VDC), Cable (AWG 24 4 pairs), Connector (Jack CB8), and Display (LED I2C 20x4).

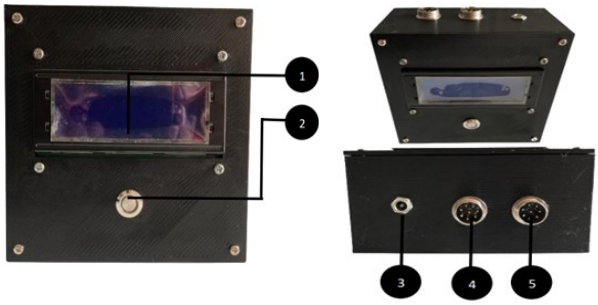


**Figure 4.** Front View of MST Device and 4 Top Sides of MST Device

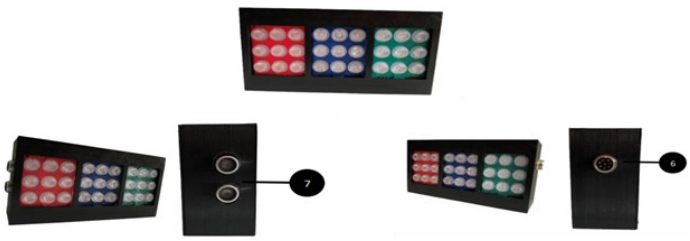


**Figure 5.** Panel Lamp Indicator


**Figure 6.** Connector Cable

Figure 3 shows the design of the developed product. Figure 4 shows the display to show the results of the test conducted, power button as the button used to turn the device on and off, Jack adapter to connect to adapter, Jack panel lamp 1 for connecting panel lamp 1and 5, and Jack panel lamp 2 for connecting panel lamp 3.

## RESULT

Figure 7. describes how to install the tools. First, connect both Lamp Indicator Panels with the device. Secondly, connect it using a connector cable. Third, position the Indicator Panel Lamp face to face for 20 meters or as needed. Fourth, make sure the device is in the middle between the two lamp indicator panels. Fifth, attach the adapter to the device to provide a voltage source. Then, the device is ready for use.

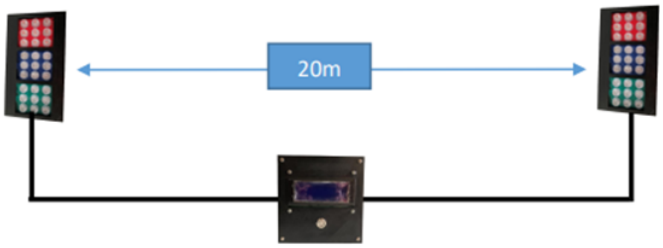


**Figure 7.** Modified VO2Max Test

The next is how to operate MST Modification of Vo2Max Test. There are some steps to operate the device. First, make sure all components are installed correctly as it is instructed. Secondly, make sure there is a power source entering the device. Third, if everything is confirmed to be correct, then press the power button on the device until it lights up red. Then, wait until the display or screen lights up and displays the words

"Welcome to MST MODIFICATION of VO2MAX TEST" and BLUE lights on both lamp indicator panels. The tool is ready for use.

**Figure 8.** Test drive of the VO2Max Test Modification product prototype

(7) the RED light does not illuminate, the participant is considered to have failed the round (8) because the participant is not considered to be in the recommended running position or the participant did not reach the finish line within the specified time. (9) All direct test results are automatically displayed on the screen/display of the device. (10) Results displayed consist of LEVEL, STAGE, and VO2Max. (11) Thus, the recorder or trainer only needs to look at the screen to find out where the test was conducted and the results of the test achieved by participants. (12) When the test is finished, press the power button and wait until all the lights and displays turn off.

This VO2Max Test Modification is suitable for endurance athletes and endurance sport players (such as football, futsal, and rugby). Doing the test requires some care. Observing the sensor and lights and keeping the results given, as the aim of this study, are things that distinguished this modified beep test of other studies. Validation of the device is required by administering correlation test, retest results, and consultations with experts in the field. The validity test results showed a (rxy) value of 0.886. Compared to the table of r = 0.282, the value of rxy is higher with a sig value of 0.000<0.6. It concludes that the VO2Max Test Modification device is reliable.

**Table 1.** Validity and Reliability of VO2Max Test

| **Validity** | **Item** | **r-calculate** | **R-table** | **Information** |
|---|---|---|---|---|
| N=30 | Validity of Vo2Max Modification Test | 0,886 | 0,282 | Valid |
| **Realibility Statistic** | **Item** | **Croncbach's Alpha** | **R-table** | **Information** |
| N=30 | Reliabel Modification Vo2Max Test | 0,957 | 0,6 | Reliable |

Product prototype tests were performed (Figure 8). After all the arrangements and operations administered correctly, the following steps are included: (1) placing the participant or subject on one of the lamp display panels, (2) asking participants or objects to be tested to be in front of the sensor connected to the screen panel of the lamp; participants or objects must not be more than 40 cm in front of the sensor because the sensor cannot detect more, (3) after confirming that the participant/subject is in front of the sensor, participants wait for the "BEEP" sound of the device or the GREEN light on the panel, (4) when the "BEEP" sounds and the GREEN light is on, participants can run to the lamp panel above them before the "BEEP" sound or the next green light comes, (5) it is repeated when the sound "BEEP" is heard or the GREEN light comes on; the athlete runs to the lamp indicator in front of him, which is 20 meters away, (6) competitors are ALLOWED to run when the RED light illuminates when the buzzer "BEEP" or the GREEN light is on because the sensor detects that the athlete is in the correct running position. But, if you hear "BEEP" or the GREEN light is on and

## DISCUSSION

This study was aimed to conduct a development of VO2Max test modification instrument device. One study discussed the development of sensor technology-based test instruments that can provide accurate and effective results. Another study aimed to develop an aerobic capacity test for rowers using minimal equipment that can be used in the field. This study found that the test developed was adequate in predicting VO2Max. In developing an instrument set for the VO2Max test modification, it is helpful to understand existing con-

cepts and methods of VO2Max measurement (Pérez-Turpin et al., 2019). It can help develop an instrument that is in accordance with the standards and principles. Determining the variables to be measured can help in designing an instrument that suits the purpose of the measurement (Pfeiffer, 2021).

Designing a measurement instrument can be done by considering the variables to be measured and the appropriate measurement method. Measurement instruments can be in the form of measuring devices or software to measure determined variables. This study developed a modified VO2Max test instruments using sensor technology in VO2Max testing. Sensor technology has several advantages, such as an accurate and effective result as stated by a study that sensor technology can provide accurate and effective results, making it a reliable tool to measure VO2Max (Peric & Nikolovski, 2017; Setiakarnawijaya et al., 2022). It could also provide convenience as the traditional VO2Max tests involve wearing cumbersome sensors while exercising in a lab. But now, anyone can get an estimate by wearing a smartwatch and moving around. Sensor technology-based devices can also be cost-effective compared to traditional VO2Max tests. Sensor technology enables real-time monitoring of VO2Max, which can be useful for athletes and coaches to adjust training programs, as mentioned in a study that using sensor technology in VO2Max testing can provide an accurate, convenient, cost-effective, and real-time monitoring of VO2Max (Taufik et al., 2021).

The development of modified VO2Max test instrument devices is an ongoing research. Although there were no specific details about the development of the devices in the previous results, several studies had discussed the use of sensor technology to provide accurate and effective results (Komaini et al., 2022). Nonetheless, these findings suggest that there are various ways to measure VO2Max, including submaximal tests and sensor technology-based devices. These methods can provide accurate results and can be used in different settings, including in the field and with diverse populations. Further research is needed to develop new instrument devices for VO2Max tests.

## CONCLUSION

This VO2Max modification device is a device developed using wireless technology. The innovation of this prototype is the wireless technology. Moreover, the users of this VO2Max instrument are different from subjects in previous studies. This VO2Max product prototype is useful for players or athletes who need to know their powerful VO2Max properties. Wireless technology is shown in Figure 7 as a prototype for training equipment innovations. This beep test version to measure the VO2Max value of the futsal athlete offers flexibility and better user comfort. The device also automatically uses time and shows results. In addition, users of this instrument receive an LED format that works automatically during the use. The loop will run continuously until the specified time. The prototype of this instrument is useful for measuring the VO2Max capacity of a futsal athlete. This VO2Max futsal prototype product is useful for players who need to know their VO2Max ability and fitness.

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## CONFLICT OF INTEREST

The authors declared no conflict of interest

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