# An Automatic Push-up Counter for Correct Posture in Calisthenics Training

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**Abstract.** One of the measures of sustainable human development is health. Sports, such as calisthenics training, promote a healthy lifestyle. In this type of training, push-up becomes the basic exercise to maintain physical strength. Despite this exercise has been regularly performed, the way to perform a correct push-up motion is rarely discussed. This study proposed an automatic push-up counter, namely PERKASA, that practically supports the correct posture in calisthenics training. It used a simple Arduino microcontroller and two ultrasonic sensors as the main component. The counting algorithm is triggered if the body is horizontally leveled. The practical test of PERKASA has shown that the device could detect up to 92% of the correct posture for push-ups. The results indicate that the tool has functioned properly to detect deficiencies in correct posture when doing push-ups.

**Keywords:** Microcontroller, Counter, Push-up, Ealisthenics, Health.

## 1 Introduction

In 2015, the United Nations adopted a universal call for Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure peace and prosperity globally. There are 17 SDGs where the action in one area will affect outcomes in others. One of the SDGs is about the promotion of health and well-being, as has been stated in SDG 3. Related to this SDG is the sport. As an enabler of sustainable development and peace, sports ensure healthy lives and promote well-being for all ages [1, 2]. Sport could also be a cost-effective tool to facilitate increased access to education, youth development, social cohesion, and gender equality [3]. Calisthenics training is a sport exercise that uses a person's body weight. This training involves little to no equipment. For swimmers, calisthenics exercise could affect body fat percentage and swimming performance [4]. Another study among male Kabaddi players showed that plyometric and calisthenics training integrated with conventional Kabaddi training would enhance explosive power, agility, trunk/lower-extremity strength, balance, and aerobic performance [5]. A calisthenics strength training program implemented in a school physical education curriculum could also enhance the fitness performance of school children [6].

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Push-ups are basic calisthenics training, which starts from a lying position, by raising and lowering the body using the arms. This exercise is useful for building upper body strength and training the triceps, chest, and shoulders. Strengthens the lower back and core by pulling the abdominal muscles [7]. Push-ups are both quick and effective exercises to build strength. Increasing the difficulty of applying the plyometric technique during push-up gives a significant impact on muscle activation [8]. It is simple and can be performed without assistance or requiring additional tools. In the military environment, push-ups are generally used for body fitness training, especially in the selection process for military recruits. The quantitative result of the push-up exercise is described by the number of successful raising and lowering motions of the body during the training. Several studies have proposed the utilization of sensor-based push-up counters. A counter in [9] could access exercise results such as agility and speed for multiple motions such as Push-Ups, Sit-ups, and Pull-Ups. Other applications of a wrist-worn fitness tracker of embedded Machine Learning in healthcare were demonstrated in fitness tracking for push-ups [10, 11]. Sensor-based Push-up counters also involved microcontrollers [12, 13, 14, 15].

The straight line between the feet and the head should be considered the correct posture of the push-ups. The procedure needs to be performed to get the correct form so the movements can be considered eligible to be counted. Among the developed push-up counters, the discussion on how to objectively count the correct posture of the push-ups is relatively rare. This issue should be related to the functionality of the counter itself. The study developed a functional prototype of a sensor-based push-up counter with a simple microcontroller arrangement that can objectively and accurately count the number of the correct posture of the push-up movement. This study considers the straight line of the down position of the body as the key to counting the correct posture for the push-up. The prototype was named *PERKASA*, an abbreviation from *PEnghitung push-up kaRya KAdet mahaSiswA* (Push-up Counter Created by Student Cadet).

## 2 Experimental setup and procedure

PERKASA was developed as an automatic counting device for the correct posture of push-ups. The developed device should be able to answer the objectivity and functionality issues. This study examines quantitatively the performance of the device in counting the correct posture for push-ups as a calisthenic training.

### 2.1 *PERKASA* device.

The developed device can be seen in **Figure 1**. The external appearance of the device is shown in **Figure 1a**, which consists of a rectangular shape of the hard casing, placement of the ultrasonic sensors, a digital display, and a channel for data and power supply. The hard casing was constructed by using the 3D printing method with ABS-type of thermoplastics filament. The internal components and their interconnection are shown in **Figure 1. b,** which consists of an Arduino Uno Compatible board, a breadboard, an LCD 1602, two ultrasonic sensor HC-SR04, an LED, a Buzzer, resistors, and jumper cables. The components to build *PERKASA* can be considered simple and economical. The system does not employ any physical input device such as a keyboard or any input button. *PERKASA* utilized the ultrasonic sensor not only to count distance but also to perform mode selection for further development. The existing power source for the microcontroller comes from an adaptor DC 5V or battery with suitable power. *PERKASA* is designed to be portable and can be powered with various external batteries commonly known as *a power bank*.

Although the display is used for indicating the number of push-ups, there are also other components that can help indicate a successful movement. Each correct posture and movement will be indicated with a visual cue through a blinking LED and an audio cue from the buzzer. The purpose of these additional audio and visual cues is to allow the user to focus on performing the movement rather than focusing on the display. The layout of the components and the cabling in the 400-holes breadboard only take several holes in the terminal strips with most pins positioned in the power bar. The simplicity in the design is not only for power requirements but also makes it easier and more economical to be produced since assembling one will not take a long time.

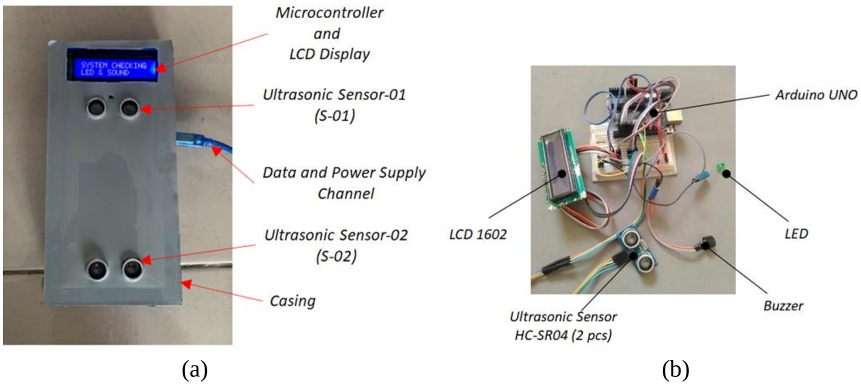


**Fig. 1.** Developed *PERKASA* device (a) External appearance, (b) Internal electronic components.

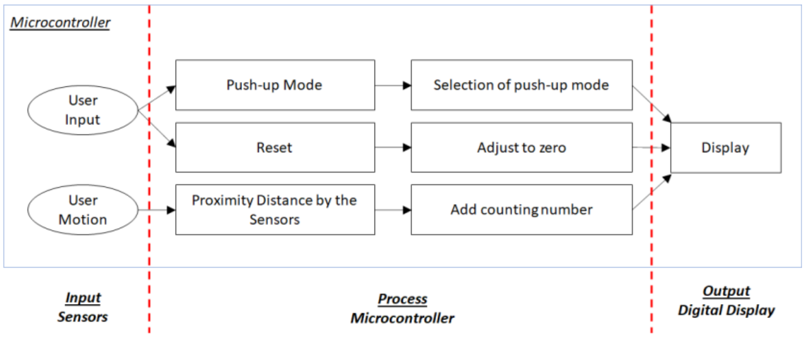


**Fig. 2.** Simplified process flow of the *PERKASA* device.

**Figure 2** shows the simplified process flow of the PERKASA. Users can control the system when it is powered on. The push-up mode is initially selected, while switching between available modes in further development could be performed by interrupting the sensors in a relatively short time, e.g. waving a hand above the sensors. If there is no object detected, represented by very high values of measured distance for 30 seconds, then the system automatically changes into reset mode, in which the displayed number becomes zero. The display is programmed to display various messages to indicate the counter system's operational condition. When the system is connected to an energy source, it will turn on and the display will indicate a welcome message. After the loading is complete, it will immediately display the number 0 (zero) indicating it is ready to receive input according to the selected mode. The display will indicate the number of push-ups with a correct posture. When the user is not performing the movement properly, the displayed number will not be increasing.

### 2.2 Testing procedure

The basis of the correct posture for push-ups exercise is that the body posture from the feet to the head is in a straight line, both when the body goes up or down. Therefore, one of the strategies to obtain straight-line information is by measuring the distance, e.g. with ultrasonic sensors, from a base level to the body continuously. *PERKASA* device with two ultrasonic sensors (S-01 and S-02) has advantages in detecting straight lines by comparing the relative differences of measured distance between the sensors. This is especially significant in the down position when the relative differences should be as minimal as possible. **Figure 3** shows the illustration of push-up counting by the *PERKASA* device. The top image of the figure shows the up position of the user, while the bottom image shows the down position of the user. The figure shows the expected straight line of the user's body, as in the red line. The bottom image illustrates the minimal difference of the measured distance by the sensors in a correct down position of the user. By following the terms of correct posture, especially in the down position, the number of successful movements or valid push-ups could be determined. The device should continuously repeat the counting process until the users finished doing the exercise.

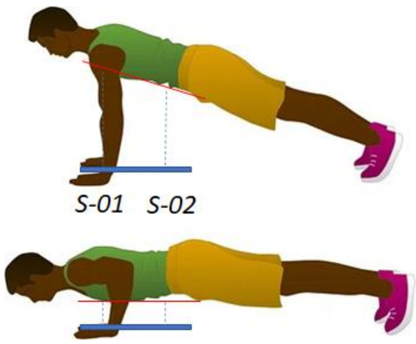


**Fig. 3.** Illustration of push-ups counting by using *PERKASA* device (Modified from [16]).

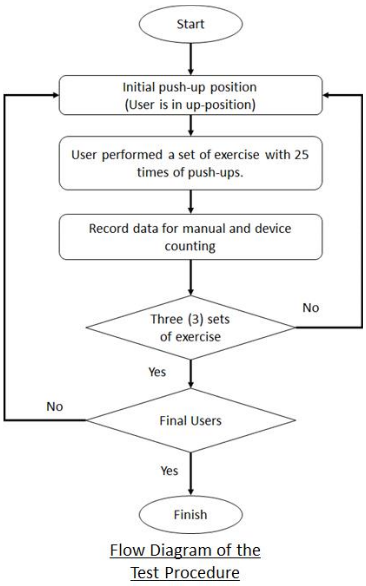


**Fig. 4.** Flow chart of the testing procedure.

To obtain the quantitative performance of the PERKASA device, a testing procedure such as in **Figure 4** was performed. There were 4 (four) student cadets of RIDU as the users. The user should initially be in the up position. Then the user performed a set of 25 times of push-ups movement. Upon the end of the set, the displayed value by the PERKASA device is recorded. The user repeated the exercises for 3 (three) times. Similar repetitive exercises were also performed by other users. The quantitative results should be obtained by comparing the count of the PERKASA device and manual counting.

(a) (b) (c)

**Fig. 5.** Performance test of *PERKASA* device (a) Initial position of the user, (b) Placement orientation of the device, (c) Counting value of the successful correct posture.

## 3 Results and Discussion

The performance tests have been performed by following the procedure in the previous chapter, as shown in **Figure 5**. The user is initially in the up position, as shown in **Figure 5a**. The placement orientation of the PERKASA device to the user's body can be seen in **Figure 5b**. The successful count of the correct posture for the push-ups movement of one user can be seen in **Figure 5c**.

The performance of the *PERKASA* device in this study is represented by the percentage of the ratio of the counted push-up. The graphical representation of the parameters is shown in **Figure 6**, while the tabulated data can be seen in Table 1. As can be seen from the figure, each user contributes to the performance evaluation. By considering that each user performed 25 times of push-ups (100%), the maximum count and the average count by the device should be important variables in analyzing the *PERKASA* device. In the figure and table, *PERKASA* could detect up to 92% of the maximum correct posture, performed by User-4. The deviation of this maximum achievable performance is relatively small at 4%, that is indicating that the device could maintain its performance during the test. Another parameter of the average counting also supports the successful functionality of the device. The repetition of the test from the same user shows that the device could detect an average of 80% correct posture. There is a relatively large deviation in this averaging parameter such as in User-4 which comprises 17%.

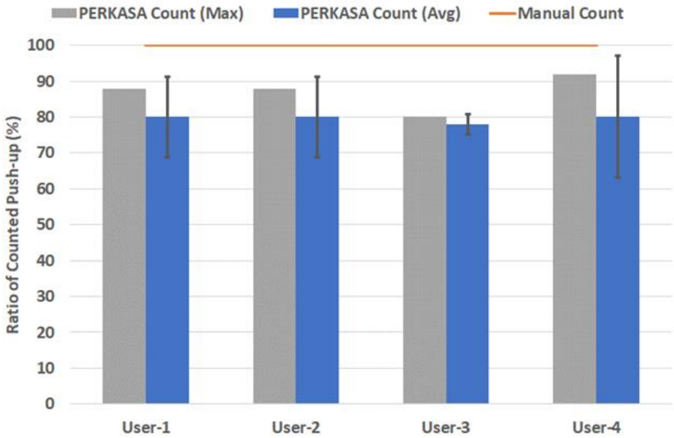


**Fig. 6.** Quantitative accuracy performance of *PERKASA* device.

**Table 1.** Performance of the *PERKASA* device.

| **Maximum Counting Performance [%]** | | | | |
|---|---|---|---|---|
| Users | User-1 | User-2 | User-3 | User-4 |
| PERKASA Count (Max) | 88 | 88 | 80 | 92 |
| PERKASA Count (Max. Avg. ± Std.Dev) | 87 ± 4 | | | |
| **Average Counting Performance [%]** | | | | |
| Users | User-1 | User-2 | User-3 | User-4 |
| PERKASA Count (Avg. ± Std.Dev) | 80 ± 11 | 80 ± 11 | 78 ± 3 | 80 ± 17 |

By considering the maximum achievable counting of the device, *PERKASA* has shown relatively high accuracy and precision in detecting the correct posture for push-up movement. The deviation might come from internal factors by the device itself such as delay in processing time for motion counting and noise level of the sensors. These factors might be enhanced by using a higher standard of proximity sensors and a more efficient microcontroller. The high deviation in repetitive tests by the same user might introduce the influence of external factors such as disturbance from the detecting plane in the user's body that might come from the user's clothes and the change of relative position between the user and the device. The deviation in the average parameter might also contribute to the quantification of the behavior of the user such as tiredness.

## 4 Conclusion

The automatic push-up counter of the *PERKASA* device has been successfully developed and tested to introduce the correct posture of push-ups as a form of calisthenics training. The development of the *PERKASA* device answers the objectivity and functionality of an automatic push-up counter. The *PERKASA* achieves 92% of maximum performance and 80% on average to detect the user's correct posture of the push-up. Recorded data analysis could reflect and improve the user behavior in doing correct posture for push-up motion in calisthenic training. Further development could include the implementation of ergonomic design principles for better human and device interaction. The application of the Internet of Things (IoT) technology to the device could enhance the efficiency of the data analysis of the user for the correct posture of push-ups.

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