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Wheelchair Control Using Bluetooth-Based Electromyography Signals

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ABSTRACT

In modern times like this, many wheelchairs have been developed with various controls, ranging from manual ones, namely by being pushed by other people or using their hands to turn the wheel, to automatic ones, such as electric wheelchairs that use joysticks and Electromyography control. The control of the electromyography signal utilizes muscles that can still be used to move the wheelchair, in this case, using the hand muscles. The use of a Bluetooth wireless system in sending electromyography signals aims to facilitate the use of a wheelchair without interference from the many connected cables so that users are more flexible in placing the electromyography sensor on the user's hand muscles. By placing the electromyography sensor on the user's arm, the electromyography sensor detects a contraction or relaxation, which is indicated by the LED flame. The output value of the sensor will be compared with a predetermined limit value. When the value is greater than the limit value, it will produce a logic low; when the value is less than the limit value, it will build a logic high. The Arduino microcontroller will calculate every low logic. The results of these calculations will be processed into serial data. The serial data will be sent to the HC-05 enslaved person via the HC-05 master wirelessly. The motor driver will execute the data so that it produces motion forward, backward, turn right, turn left and stop. It is hoped that this tool can help individuals with limited movement so that they do not have difficulty in mobility.

Keywords: Bluetooth; Electromyography; Hand muscle; Wheelchair; Wireless

1. INTRODUCTION

Paralysis is one of the most common causes of stroke(Rompas & Bawotong, 2019). Paralysis is caused due to an injury to a part of the central nervous system. In addition to central nervous system injuries, paralysis is also caused by certain diseases such as stroke, spinal cord, multiple sclerosis, cerebral palsy, post-polio syndrome, and others(Viani et al., 2021).

A person who has paralysis in the legs can use a wheelchair to support their mobility in carrying out their daily activities(Nur Sasongko, 2020). A wheelchair is one of the medical equipment used to help those who have difficulty walking. People have paralysis, deformity of the legs, motor nerve problems, and old age. People with special needs depend on wheelchairs because, without a wheelchair, it is impossible for people with disabilities to perform daily tasks(Prasetiyo & Suwarno, 2019)(Ferdiansyah & Susanto, 2020).

People with mobility impairments usually use manual wheelchairs in hospitals. Where the user pushes himself with the wheelchair wheels that are turned by hand or by being pushed by others(Fatoni et al., 2022). Although it would be ideal for wheelchair users to be able to easily adjust their wheelchair to the desired level of movement, the truth is that some people may not be able to do so due to a physical state that is not normal (Junior & Arifin, 2019). It can be replaced by an automatic control system whose subject is replaced by a device called a controller, where the task of the controller itself is to help the wheelchair run without any encouragement from the subject of living beings(Djatmiko, 2016)(Hazbi & Ma, 2023). Microcontrollers can be the basis for the performance of system automation because they can be integrated with input and output peripherals through each board so that they can be a solution in meeting technological needs(Seidel & Berente, 2020)(Jagtap et al., 2021).

In modern times, various wheelchair controls have been invented, ranging from manual ones, such as being driven by people and turning the wheels by hand, to automatic ones, such as electric wheelchairs with joysticks(Fahrozi, 2020). But joystick use is difficult to use for elderly people and patients with some disorders that cause limb paralysis, such as partial tetraplegia, multiple sclerosis, Parkinson's disease, and stroke, so they lose the ability to use their hands(Akbar et al., 2021).

Based on the research "EMG Signal Processing as a Control Command for Electric Wheelchairs" by Jeffry Glen Sitanaya, Tasripan, and Achmad Arifin in 2018, it can be concluded that the research went according to its

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function, but there are still many cables connected, making it difficult for users to put electromyography sensors and operate the wheelchair, and also when using the cable system from the sensor to the actuator affects the work sensor due to the presence of reverse voltage when the motor is working(Glen Sitanaya et al., 2019).

From these problems, in this study, "Wheelchair Control Using Bluetooth Based Electromyography Signal" was made. With this system, the hope is that the signal from the electromyography sensor can control the running of the wheelchair, while Bluetooth communication can be used to send signals from the sensor then to the DC motor(Wirawan, 2020). So that there are no more cables connected from the sensor to the actuator so as to minimize the back voltage from the motor to the sensor. This system is one of the solutions to help individuals who experience movement limitations so that they do not have difficulties with mobility.

2. LITERATURE REVIEW

Based on the research "EMG Signal Processing as a Control Command for Electric Wheelchairs" by Jeffry Glen Sitanaya, Tasripan, and Achmad Arifin in 2018, it can be concluded that the research went according to its function, but there are still many cables connected, making it difficult for users to put electromyography sensors and operate the wheelchair, and also when using the cable system from the sensor to the actuator affects the work sensor due to the presence of reverse voltage when the motor is working(Glen Sitanaya et al., 2019).

3. METHOD

The study centered on wheelchair control using signals from electromyography sensors and sending signals that have been obtained from electromyography sensors to wheelchairs via two HC-05 Bluetooth modules. The Bluetooth module will act as a sender (master) and receiver (slave). The Bluetooth module will send the commands given from the master microcontroller to the slave microcontroller, and the data received from the slave microcontroller will be passed on to the motor driver so that it turns into the electromotive force of the DC motor (Nugroho & Sutikno, 2021).

3.1 System Design

The design of this tool, there are three parts. The first part of the system design process involves wiring design, which outlines the components that will be used in the system and the connections between them. The second part is designing a block diagram, which shows the input, processing, and output components of the system and how they relate to each other. The third part involves creating a flowchart, which illustrates the system's workflow and how the various components interact with each other. These three parts provide a comprehensive understanding of the system's design and operation.

3.2 Wiring Design

This wiring design consists of 2 Arduino uno as a microcontroller. The first Arduino functions as a master (sender), the second Arduino functions as a slave (receiver), Arduino which functions as a master there is an electromyography sensor, a 7 volt battery, Bluetooth HC05, a push button, and LEDs, in the Arduino that function as a slave. There is Bluetooth HC05, a BTS motor driver BTS7960, and the output of a 5 volt step down.

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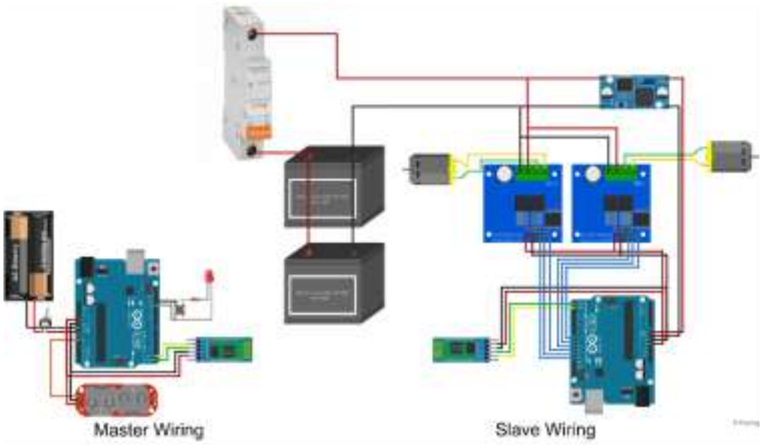

Fig. 1 Wiring Design

Table 1
Arduino Master Port Usage

NO	Arduino master port	Usage
1	A0	SIG EMG SENSOR
2	5V	+ EMG SENSOR
3	GND	- EMG SENSOR
4	TX	RX HC-05
5	RX	TX HC-05
6	5V	VCC HC-05
7	GND	GND HC-05
8	D13	PUSH BUTTON
9	D13	LED
10	VIN	OUT + BATTERY
11	GND	OUT - BATTERY

Table 2
Arduino Slave Port Usage

NO	Arduino slave port	Usage
1	D8	RPWM BTS7960-1
2	D9	LPWM BTS7960-1
3	D10	EN BTS760-1
4	5V	5V BTS7960-1
5	GND	GND BTS7960-1
6	D11	RPWM BTS760-2
7	D12	LPWM BTS7960-2
8	D13	EN BTS7960-2
9	5V	5V BTS7960-2
10	GND	GND BTS7960-2
11	TX	RX HC-05
12	RX	TX HC-05
13	5V	VCC HC-05
14	GND	GND HC-05

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15	VIN	OUT+ LM2596	STEPDOWN
16	GND	OUT- LM2596	STEPDOWN

Table 1 and Table 2 show the cable connection between Arduino uno and some supporting components such as electromyography sensors, Bluetooth HC05, BTS 7960 motor driver, push button, led, and battery. This cable connection must be made correctly for the system to learn well.

3.3 Block Diagram

The system diagram block can be seen in Figure 2.

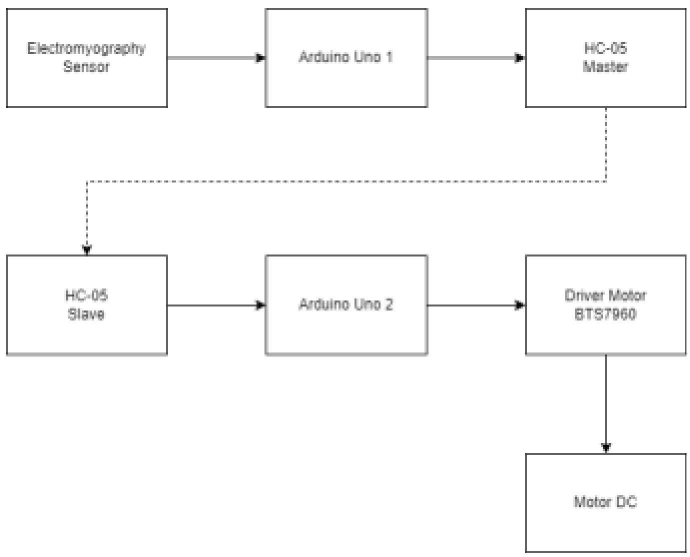

Fig. 2 System Block Diagram

From figure 2 can be explained that the hardware consists of 7 parts, namely electromyography sensor, Arduino 1, Bluetooth module HC-05 (master), Bluetooth module (slave), Arduino 2, BTS7960 motor driver, and dc motor. The master diagram block has an electromyography sensor component, Arduino 1, and a Bluetooth module HC-05, which acts as a master or sender. While in the slave block diagram section, namely the HC-05 Bluetooth module which acts as a slave or receiver, Arduino 2, BTS7960 motor driver, and dc motor. The output of the electromyography sensor is in the form of an analog signal, then this signal is processed by Arduino 1 into a digital signal through the ADC process, and the results of the digital signal are changed to serial form. The output of Arduino 1 is transmitted to the slave via the master HC-05. The output of the master received by the HC-05 slave is in the form of a serial form, then processed by Arduino 2 and passed to the motor driver so that it turns into a dc motor electromotive force.

3.4 System Flowchart

3.4.1 Master Flowchart Program

This master flowchart starts by connecting the Bluetooth master and slave. If it is connected, the electromyography sensor detects contraction or relaxation then the sensor output value will be compared with the predetermined limit value. When the value is greater than the limit value, it will output logic low marked by led, and when the value is less than the limit value, it will produce high logic. The logic used to be able to generate calculations is low logic. The Arduino microcontroller will calculate any low logic that appears. If there is no low logic for 1 second, then the calculation is not continued, and the result of the calculation will be processed into serial

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data. If the calculation results are 1, it will be changed to serial data 1. If the result is 2, it will be changed to serial data 2. If the result is 3, it will be changed to serial data 3. If the result is 4, it will be changed to serial data 4, and if the result is 5, it will be changed to serial data 5, and then the serial data will be sent to the HC-05 slave via the HC-05 master wirelessly.

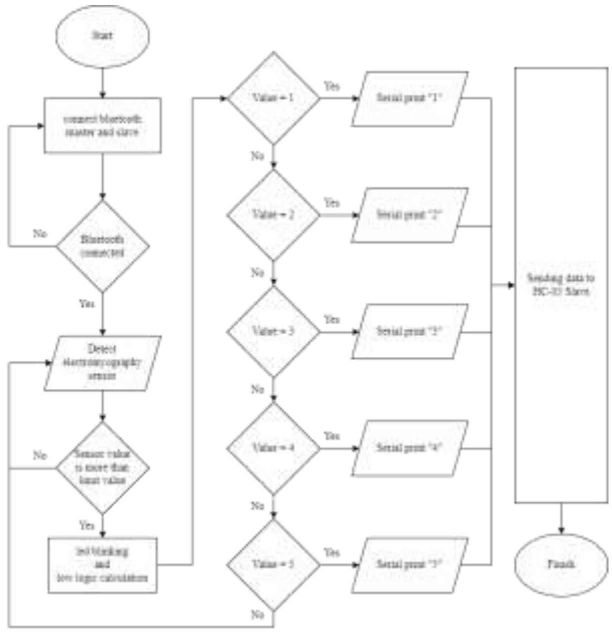

Fig. 3 Master Flowchart Program

3.4.2 Slave Flowchart Program

This flowchart begins with the reading of the data that has been sent by the HC-05 master, and then the data will be executed by the motor driver so as to produce forward, reverse, right turn, turn left, and stop. If the result of the reading of HC-05 slave serial 1, then the wheelchair stopped. If the result is serial 2, then the wheelchair will move forward. If the result is serial 3, then the wheelchair will move backward. If the result is serial 4, then the wheelchair will turn right. And if the result is serial 5, then the wheelchair will turn left.

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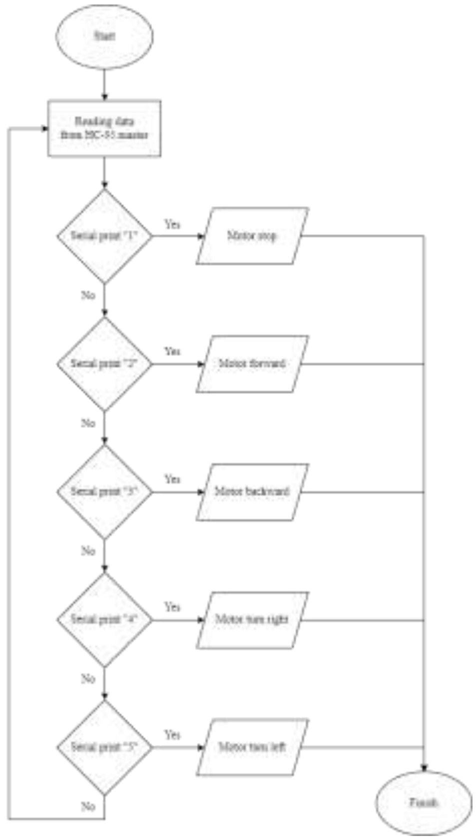

Fig. 4 Slave Flowchart Program

3.5 Accuracy and Precision

Testing is carried out by comparing the measurement results of tools made with commonly used standard tools. In addition, testing is also carried out by taking results from actual and real-time conditions.

The calculation is carried out using several formulas, among others:

$$Deviation = (nSensor - nMeasure) \tag{1}$$

Which is the deviation formula:

$$Average\ Value = \mu = \frac{x_1+x_2+x_3+x_4+x_5}{n} \tag{2}$$

which is the average value formula; standard deviation formula(Yanti & Sulistiyowati, 2022).

$$\sigma = \sqrt{\frac{\sum_{i-1}^{x}(x_i-\mu)^2}{n}} \tag{3}$$

and formula percentage accuracy and percentage the error can be expressed below(Yanti & Sulistiyowati, 2022).

$$\%Accuracy = \left\{1 - \left|\frac{Yn-Xn}{Xn}\right|\right\} \times 100\% \tag{4}$$

$$\%Error = \left\{\left|\frac{Yn-Xn}{Xn}\right|\right\} \times 100\% \tag{5}$$

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4. RESULT

Here are the results of the realization of the tool. In Figure 5, it is the result of the realization of the tool. The components of such a tool will be described by numbering as follows: 1. Battery 12 volt, 2.DC Motor, 3. MCB DC 10A, 4. BTS7960 Driver motor, 5. Step down 5 volt dc, 6. Arduino 2, 7. HC-05 (slave), 8. Battery 7 volt, 9. Arduino 1, 10. HC-05 (master), 11. Push button, 12. Electromyography sensor, 13. Switch, 14. Led.

Fig. 5 Result of tool realization

How to use this tool is as follows :

1. Users sit quietly in a wheelchair
2. Install the electromyography sensor on the user's right hand or left hand
3. Users can control the wheelchair by clenching the hand attached electromyography sensor as a sign of contraction of the hand muscles, 1 contraction to stop, 2 times contraction for forwarding motion, 3 times contraction for reverse motion, 4 times contraction for right turning motion, 5 times contraction for left turning motion, 5 times contraction for a left turn

4.1 12 Volt Battery Testing

Table 3 shows 10 times the testing of a 12 volt battery with a multitester. Here the author uses 2 12 volt batteries arranged in parallel so as not to change the voltage of the battery. This test obtained a deviation of 0.43 and an accuracy of 96.7%. This does not affect the working system of the tool because the voltage of 12 volts is the minimum voltage of the tool, so when the voltage is greater than the minimum voltage, it will not affect the working system of the tool. This 12 volt voltage will be used for the dc motor power supply and lowered using step-down for the power supply of the output control circuit.

Table 3

12 Volt Battery Testing

Testing to -	Voltage needed (V)	Multimeter (V)	Deviation (V)	Accuracy (%)
1	12	12,5	0,5	96
2	12	12,5	0,5	96
3	12	12,5	0,5	96
4	12	12,4	0,4	97
5	12	12,4	0,4	97
6	12	12,4	0,4	97
7	12	12,4	0,4	97
8	12	12,4	0,4	97
9	12	12,4	0,4	97
10	12	12,4	0,4	97
Average	12	12,43	0,43	96,7

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4.2 7 Volt Battery Testing

Table 4 shows 10 times the testing of a 7 volt battery with a multitester. This test obtained a deviation of 0.54 and an accuracy of 92.5%. This does not affect the working system of the tool because the voltage of 7 volts is the minimum voltage of the tool, so when the voltage is greater than the minimum voltage, it will not affect the working system of the tool. This 7 volt voltage will be used for the power supply of the input control circuit.

Table 4

7 Volt Battery Testing

Testing to -	Voltage needed (V)	Multimeter (V)	Deviation (V)	Accuracy (%)
1	7	7,7	0,7	90
2	7	7,6	0,6	92
3	7	7,6	0,6	92
4	7	7,5	0,5	93
5	7	7,5	0,5	93
6	7	7,5	0,5	93
7	7	7,5	0,5	93
8	7	7,5	0,5	93
9	7	7,5	0,5	93
10	7	7,5	0,5	93
Average	7	7,54	0,54	92,5

4.3 5 Volt Step Down Testing

Table 5 shows 10 times 5 volt step down tests with a multitester. This test obtained a deviation of 0.0 and an accuracy of 100%, and it can be concluded that the voltage used of 5 volts in this tool is accurate. This 5 volt voltage will be used for the power supply of the output control circuit.

Table 5.

5 Volt Step Down Testing

Testing to -	Voltage needed (V)	Multimeter (V)	Deviation (V)	Accuracy (%)
1	5	5	0	100
2	5	5	0	100
3	5	5	0	100
4	5	5	0	100
5	5	5	0	100
6	5	5	0	100
7	5	5	0	100
8	5	5	0	100
9	5	5	0	100
10	5	5	0	100
Average	5	5	0	100

4.4 Testing Connection of Bluetooth Master and Bluetooth Slave

Table 6 shows 10 times the test of Bluetooth master and Bluetooth slave connections. From the test results, connection results were obtained by waiting for a time of 4 seconds to 5 seconds. In conclusion of this test, the connection speed of Bluetooth master and Bluetooth slave is medium. In table VI, it can be seen that in the 10 trials, the connection of Bluetooth master and Bluetooth slaves are all optimally connected. The results of this test show that the Bluetooth connection is running normally so that the device can be used properly.

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Table 6.

Testing Connection of Bluetooth Master and Bluetooth Slave

Testing to-	Connection Bluetooth master and slave		Speed
	Condition	Waiting Time (s)	
1st Test	Connected	5	Medium
2nd test	Connected	5	Medium
3rd test	Connected	4	Medium
4th test	Connected	5	Medium
5th Test	Connected	4	Medium
6th test	Connected	5	Medium
7th test	Connected	4	Medium
8th test	Connected	5	Medium
9th test	Connected	5	Medium
10th Test	Connected	4	Medium

4.5 Driver Motor BTS7960 Testing

Table 7 shows 10 tests of the BTS7960 motor driver. From the test results, it can be concluded that the instruction with its action is appropriate. The results of this test show that the BTS7960 motor driver is running normally.

Table 7

Driver Motor BTS7960 Testing

Testing to-	Driver motor BTS7960		Description
	INPUT	OUTPUT	
1st Test	LOW-LOW	STOP	Success
2nd test	HIGH-LOW	CW	Success
3rd test	LOW-HIGH	CCW	Success
4th test	HIGH-HIGH	STOP	Success
5th Test	HIGH-LOW	CW	Success
6th test	LOW-HIGH	CCW	Success
7th test	LOW-LOW	STOP	Success
8th test	HIGH-LOW	CW	Success
9th test	LOW-HIGH	CCW	Success
10th Test	HIGH-HIGH	STOP	Success

4.6 Electromyography Sensor Testing

Table 8 shows 10 sensor electromyography tests with 10 different subjects and different hands. From the test results, there are different results when the muscles contract and when the muscles are relaxing. At the time of contraction, the signal value produced by the electromyography sensor is very large compared to when the muscles are relaxing. This indicates that the electromyography sensor is functioning normally so that it can be used properly.

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Table 8

Electromyography Sensor Testing

Subject	Electromyography sensor			
	Right hand		Left hand	
	Contraction	Relaxation	Contraction	Relaxation
1	110	30	98	27
2	131	54	153	27
3	117	26	81	40
4	145	61	134	31
5	141	30	107	37
6	121	37	145	32
7	59	22	99	23
8	95	20	107	30
9	145	24	108	29
10	113	44	169	33

4.7 Wheelchair Operating Testing

Table 9 shows 10 tests of wheelchair operation with 10 different subjects. From the test results obtained the result that the wheelchair can be operated properly, but before operating, the wheelchair requires a different set of limit values for each subject, it is done because the contraction and relaxation values of each subject are different.

Table 9

Wheelchair Operating Testing

Subject	Wheelchair operating			
	Forward	Backward	Turn right	Turn left
1	Success	Success	Success	Success
2	Success	Success	Success	Success
3	Success	Success	Success	Success
4	Success	Success	Success	Success
5	Success	Success	Success	Success
6	Success	Success	Success	Success
7	Success	Success	Success	Success
8	Success	Success	Success	Success
9	Success	Success	Success	Success
10	Success	Success	Success	Success

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5. CONCLUSION

Based on the results of the tests that have been carried out, it can be concluded that : (1) Electromyography sensor testing was performed 10 times with 10 different subjects and different hands. Electromyography sensor testing runs normally and produces different values when muscle contraction and relaxation. (2) Testing the Bluetooth connection of the master and Bluetooth slave runs optimally so that the input signal from the master circuit used as input can be sent successfully to the slave circuit used as output, the result of connection testing by waiting for a time of 4 seconds to 5 seconds after which it can be connected properly. (3) The 12 volt battery test obtained a deviation of 0.43 and an accuracy of 96.7%, and this is because the result of the measurement is greater than the required voltage, but it does not affect the working system of the tool because the voltage of 12 volts is the minimum voltage of the tool. (4) The 7 volt battery test obtained a deviation of 0.54 and an accuracy of 92.5%, and this is because the result of the measurement is greater than the required voltage, but it does not affect the working system of the tool because the voltage of 7 volts is the minimum voltage of the tool. (5) Testing of wheelchair operation was carried out with 10 different subjects. This test went normally and resulted in the appropriate wheelchair motion, but it required setting the limit value for each subject before running the tool, as the result of each subject's contraction and muscle relaxation was different.

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