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Portable designed device with flexor sensor for scoliosis rehabilitation among young male and female athletics

Archibald Danquah-Amoah and Dr. Amit Alexander Charan

Abstract
The spine is made up of three slight curves one is found in the neck, one in the upper back, and the last one situated in the lower back. These curves are normal and can be seen from a side view. Seeing from a back view, the spine should appear straight. Seeing from the back view if a spine have side to side curve it is called scoliosis. The normal Human spine is known to have a natural "S" curve. spine curvature can be classified into kyphosis and lordosis. Scoliosis is present in 0.2 – 6% of the population, affecting females in most cases and young male and female engaged in rhythmic gymnastics and altheles. A flexor sensor with buzzer alarm has been set to a particular angle around 10 or more degrees was designed and placed at he back of the atheles to dectect mild or moderate scoliosis, therefore when the individual bends during standing above 10 degree or more, beyond its own acceptable curvature degrees the alarm blows a sound to alert the human subjects or the young athletes to be upright or stand well.

Keywords: Kyphosis, lordosis, scoliosis, sensor, and buzzer

Introduction
The spine is made up of a column of small bones, or vertebrae, that gives support the entire upper body. The column is classified into three major parts of vertebrae: The cervical (C) vertebrae consist of the five spinal bones that support the neck. The thoracic (T) vertebrae are made up of twelve spinal bones that join to the rib cage. The lumbar (L) vertebrae consist of five lowest and largest bones of the spinal column. Most of the body's mass and stress falls on the lumbar vertebrae. Next to the lumbar region is the sacrum, this is a shield-shaped bony structure that joins with the pelvis at the sacroiliac joints. At the end of the sacrum are two to four tiny, partially fused vertebrae known as the coccyx or tail bone. The spine is made up of three slight curves one is found in the neck, one in the upper back, and the last one situated in the lower back. These curves are normal and can be seen from a side view. Seeing from a back view, the spine should appear straight. Seeing from the back view if a spine have side to side curve it is called scoliosis shown in Figure 1.1 also the curves can be very small (mild). It may be slightly bigger (moderate) and lastly it may be sharp (severe). The vertebras of the lower back are connected by ligaments which attach bone to bone, and tendons that connect muscle to bone. The normal Human spine is known to have a natural "S" curve. spine curvature can be classified into kyphosis and lordosis. The curve seen from the side when the spine is bent forward is known as Kyphosis and it has Curvature of the spine of 50 degrees or more this is the main characteristic of kyphosis, which usually presents itself in the form of a severely rounded upper back. Most it is common in older women; this type of curvature can develop at any age. Lordosis is a curve seen from the side in which the spine is bent backward that is when spine has significantly curved inward may be a sign of lordosis, sometimes referred to as swayback. In some cases, the curvature will be flexible enough to correct itself when moving forward, which often means there will be no need for medical intervention. People with scoliosis can also acquire additional curves to either side, or the bones of the spine twist on each other like a corkscrew. These curves can't be corrected simply by trying to stand up straight. Scoliosis is a disorder that causes an abnormal curve of the spine, or backbone. The spine has normal curves when looking from the side, but it should appear straight when looking from the front. Other types of scoliosis: Congenital Scoliosis: This type of scoliosis that is caused by the vertebrae that are not properly formed, it occurs in the early in development usually in the first 6 weeks of embryonic formation. Adolescent Scoliosis: This type of scoliosis that usually occurs between the ages of 10-18 years it is the most type of scoliosis. Degenerative Scoliosis: It occurs over the age of 18. It typically develop as joint in the spine degenerates and curves Neuromuscular Scoliosis: It is irregular spinal curvature

caused by disorders of the brains, spinal cord and muscular system. Syndromic Scoliosis: It is a sideways curve of the spine developed as part of the syndrome. However, the symptoms of scoliosis can be given as one shoulder being higher than the other, one hip is higher than the other, one rib cage higher than the other, one shoulder blade is higher than the other, uneven leg length, and consistency of features on one part of the body. Scoliosis is mostly occurs two times more common in girls than boys in most parts of globe. It can be seen at any age in life, but it is mostly intense in those over 10 years old. However, there is no relationship between the severities of the curves seen and various age groups. In most cases, the cause of scoliosis is unknown (idiopathic). This type of scoliosis is described based on the age when scoliosis develops. Scoliosis below 3 years old, it is called infantile idiopathic scoliosis. Scoliosis that develops between 3 and 10 years of age is called juvenile idiopathic scoliosis, and scoliosis that develop with person over 10 years old is known as adolescent idiopathic scoliosis (Gummerson *et al.,* 2011) [1]. Scoliosis is present in 0.2 – 6% of the population, affecting females in most cases (Wilson, 2013) [5]. Young girls engaged in rhythmic gymnastics (Micheli, 1983; Cirillo and Jackson, 1985; Sward *et al.,* 1990) [2, 3, 4] as a profession have a 10-fold increased risk for scoliosis to scoliosis. When people fail to detected scoliosis and checkitearlier it can affect the performance of swimmers (Becker, 1986) [7], athletes (Green *et al.,* 2008; Stosic *et al.,* 2011) [6], professional musicians and dancers (Bird and Pinto, 2013; Steinberg *et al.,* 2013) [8, 9]. Angle displacement monitoring sensors body devices are also used to rehabilitate body posture. Most of these devices used are for mild scoliosis which does not need surgery. Examples of these are Lumo left, laser device and Unbiased posture braces are also used for scoliosis posture corrections just to mention a few. Scoliosis affects a lot of young girls engaged in rhythmic gymnastics having about 10-fold increased risk to scoliosis in the globe. Professional dancers and athletes are also highly susceptible to scoliosis. The designed device can be used for rehabilitation of juvenile idiopathic scoliosis, congenital scoliosis, degenerative scoliosis, neuromuscular scoliosis, syndromic scoliosis, adolescent idiopathic scoliosis among young athletics. Effect of mild Scoliosis (less than 20 degrees): Mild scoliosis is not so dangerous and requires no treatment other than to monitor. Effect of moderate Scoliosis (between 25 and 70 degrees): It is still not clear whether moderate scoliosis causes significant health problems. In one study (Kesten *et al.,* 1991) [11], adults with moderate scoliosis had their normal lung performing well, although they had difficulty exercising. (The researchers believed that this low exercise tolerance might have been because many patients with scoliosis do not engage in regular physical activity). Effect of severe Scoliosis (Over 70 degrees): If the curvature exceeds 70 degrees, the severe twisting of the spine that occurs in structural scoliosis can cause the ribs to press against the lungs, restrict breathing and reduce oxygen levels. Asher and Burton (2006) [6] concluded that almost two-thirds of patients with curves of 90 degrees and under had less than 80% of normal lung capacity. The distortions can also affect the heart and cause dangerous changes. Effect of very severe Scoliosis (Over 100 degrees): Asher and Burton (2006) [6] stated that if the curve reaches over 100 degrees, both the lungs and heart can be injured. Patients with this degree of severity are susceptible to lung infections and pneumonia. Curves greater than 100 degrees increase mortality rate, but this problem is very uncommon. Suken *et al*. (2009) [12] stated that the degree of the spinal curve is nearly always calculated using a technique known as the Cobb method. Using an X-ray on the spine, the examiner draws two lines. One line extends out and up from the edge of the top vertebrae of the curve. The second line extends out and down from the bottom vertebrae. A perpendicular line is then drawn between the two lines. The point of intersecting angle is measured to determine the degree of curvature. The Cobb method has narrow scope of usage, because it cannot fully determine the three-dimensional aspect of the spine. It is not as effective, then, in defining spinal rotation or kyphosis. It also tends to over-estimate the curve. Other diagnostic tools are needed to make a more accurate diagnosis. An improved technique using calculations based on geometric principles of the apex of the curve as well as the top and bottom of the curve may prove to be accurate in determining all the dimensions of the curve**.** For kyphosis, on lateral view, a line is drawn along the superior end plate of the superior end vertebra and a second line drawn along the inferior end plate of the inferior end vertebra. The angle formed by intersection of lines perpendicular to above mentioned lines is Cobb angle for kyphosis. Myers (1980) [14] made a very important invention by provide a belt having a posture warning device which advises the wearer by an audible tone when he has allowed his abdominal muscles to relax to an unsightly extent. The belt is not readily noticeable when being worn, but instead looks like an ordinary belt. It has no additional weight when worn and not expensive to construct it. Tosbio *et al*. (1992) [13] made an invention relates to a medical belt for holding mainly lumbers of human beings in order to alleviate pain in the lumber by reducing a load to be imposed on the lumber or waist. Conventionally, some medical belts, stays or figure beauty supports, or belts for shaping waist have been made of rubber in a shape of ring, or leather or plastic material, and they have metal-made-fastening fixtures fixed to the ends of the various belts mention above. However, such ring-like belts made of rubber have poor ventilation resulting in stuffiness of the body. As a result, the wearer of the belts feels uncomfortable after a long time wearing. According to other inconvenience of the conventional belts, it is impossible to adjust the length or fitness according to the waist size of the wearer or user of the belt, and it is troublesome to put on and take off the belts. Such belt provided with a fastening fixture fixed to an end portion of the belt has a limitation in its length adjustment and it is impossible to adjust in a wide range of the length. Consequently, it has been necessary to manufacture a number of belts having various sizes. Zablotsky *et al.* (1993) [15] reported that the air inflatable belts (Lumbosacral belt)worn around the waist of a person are well known as therapeutic appliances for reducing or protecting against incidents of pain resulting from spasms and fatigue of the muscles and nerves in the lumbar or lumbar and sacral regions of the spine. Such belts include one or more air bladders which are inflatable through the use of a detachable aspirator bulb as disclosed. The belt is attached to the person's body with the bladder or bladders overlying the lumbar and sacral regions, and the bladder or bladders are inflated to provide the amount of pressure desired by the wearer. The pressure provides mechanical support for the muscles and ligaments in the lower spine area and provides static stretch to the erector spine muscle and aids in the prevention and elimination of spasms by maintaining these muscles in a more stretched and relaxed state. Brucker (1996) [16] invented the stomach muscle or posture monitoring belt for the improving of the body

posture by sensing the expansion of the abdominal muscles and provide a warning sound when stomach muscle expansion exceeds a preset limit. The length of the belt strap is adjustable. The adjustment is sets at a limit in which the monitoring or warning device contained in the belt housing will emit an audible sound when the stomach muscles expand beyond a preset limit. The audible sound, which comes out can be a relatively quiet and clicking sound. It is a short impulse type audible sound which last for a fraction of a second. It does not give continuous sound while the abdominal muscles are under expansion. The warning device is purely mechanical in function and does not generate an electronically produced alarm or buzzer sound that can be annoying and discouraging to the user when the belt is worn in public such as in social gatherings and meetings. Kline (1998) [17] invented posture training device which uses a frame and a vibration module disposed in the center of the frame. The vibration module floats within the frame, and the frame with vibration module can be held against a person's back by a belt or garment to generate a vibro-tactile signal when the person assumes a poor posture. Specifically, the device is held, by forces at its perimeter, against a reference surface of the back, and when the person's backbone is flexed, the midsagittal or transverse curvature of the back becomes relatively convex. Consequently, the reaction force at the center of the device increases, moving the module within the frame to thereby cause the module to vibrate. The device provides no support to the body, to stop the vibration, the person must use his or her muscles to move the body back to a good posture, and then the vibration will stop. This will and trains the muscles. All these inventented devices never used flexor sensor. The designed device was set at 10 degrees using a flexor sensor which is not injurious to human subjects. The sensor is also connected to an alarm system to give an alarm when the spinal curvature is more than 10 degrees to alert the person of bad posture or having a spine curvature disorder. This device does not cure scoliosis neither does it gives the amount of angle of curvature. The designed device can only use for detection of mild or moderate scoliosis disorder also to rehabilitate the human subjects with scoliosis disorders. The was designed at Shuats Allahabad and cetal laboratories limited Chennai all in India. It was tested on 60 athletes which comprises of 30 male and 30 female. The validation of designed device was done under the supervision of Dr. Mohammed Younus, Consultant Orthopaedician & Joint Replacement Sugeon & Ilizarov Specialist at MIOTS Hospital, Allahabad, U.P.

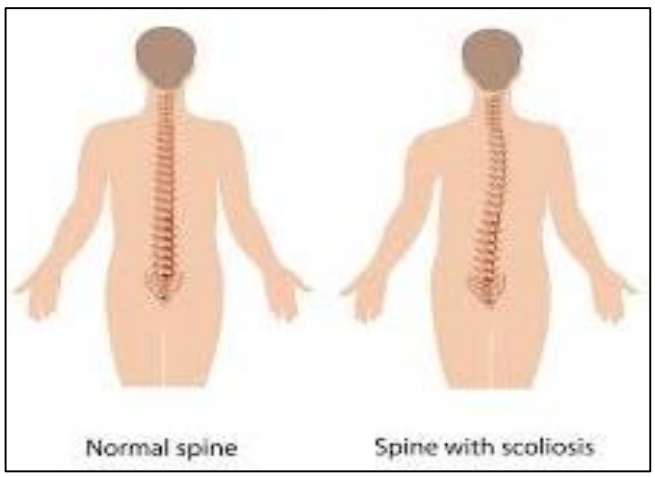

Fig 1.1: Normal and abnormal spine curvatures

Materials and methods

In this research work SPSS (Statistical package for social sciences) which is a software tool and excel software tool was used for the analysis and drawing of various types of graphs and tables, also t or z test was used as the statistical testing tool. Furthermore, a portable and simple device was design to detect and rehabilitate a young athletes between the ages of 18 – 25 years suffering from scoliosis. This device was tested on 60 athletes. All materials were acquired locally for this project. This research was done at various locations and analysis was performed at SHUATS, Allahabad, India and Ghana.

Materials

Components for biocompatible leather belts

Leather belt, Cushion form liner, locking system for the belt.

Angle detecting flexor sensor

Flexion sensors, (from Latin flectere, 'to bend') also called bend sensors, measure the amount of angle deflection caused by flexing the sensor. There are various ways of sensing deflection, from strain-gauges to hall-effect sensors. They convert the change in bend into electrical resistance – the more the angle of bend, the more the resistance value. Bending the sensor at one point to a prescribed angle is from 0˚to 90˚ provides the exact change in resistance value with respect to the radius of curvature. The smaller the radius of curvature and the more the whole length of the sensor are involved in the deflection, the greater the resistance will be (which will be much greater than the resistance achieved if the sensor is fixed at one end and bent sharply to a high degree). The sensing parameter is defined as “flex angle multiplied by radius”.

Microcontroller

Description of 8-bit microcontroller

AVR ATMega328 is Atmel’s high performance, low power 8-bit microcontroller in a pint-sized TQFP package which consumes very low power without any compromise in the performances (Figure 2).

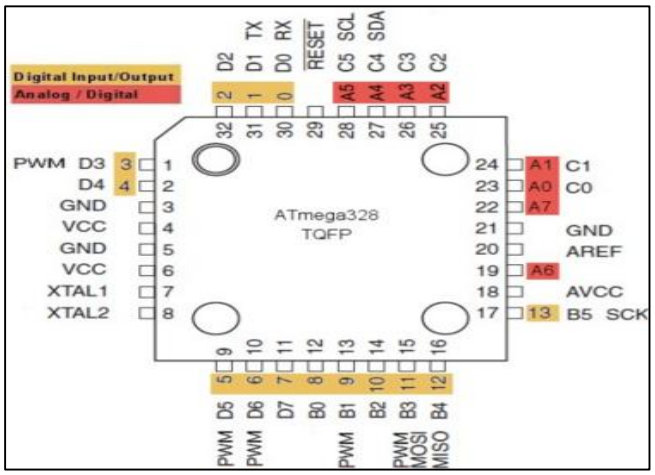

Fig 2: Microcontroller AVR ATM ega 328

Methodology and the procedure for operating the biofeedback device

Block diagram of the device showing various components attached

The biofeedback sensor was placed at the back (at the place where backbone is seen curved). A wire was connected from

the biofeedback sensor to an alarm system place in the device. The biofeedback sensor has been set to a particular angle around 10 or more degrees. Therefore when the individual bends forward during standing above 10 degree or more, beyond its own acceptable curvature degrees the alarm blows a sound to alert the human subjects or the young athletes to be upright or stand well. This portable device was tested on males and female young athletes. By using of SPSS (Statistical Package for Social Sciences) Software tool and Excel Software tool various types of graphs and tables was drawn to show the various remarks from individuals using the device. Also the length of time for the rehabilitation process to be achieved in an individual was determined (Figure 3).

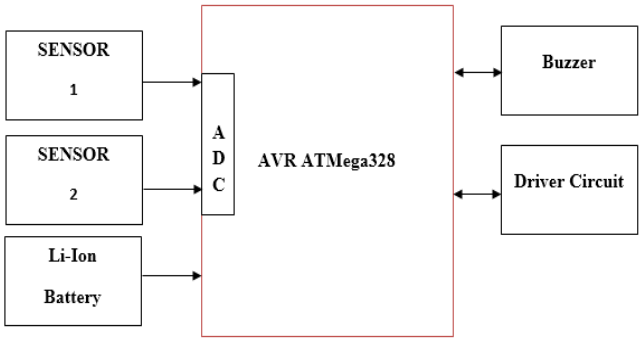

Fig 3: Block diagram of the device showing the various components attached

Flowchart for operation concept of the device

The flowchart below is showing the working principles of the device and how the signals will be converted from analog to digital and where the information will be stored.

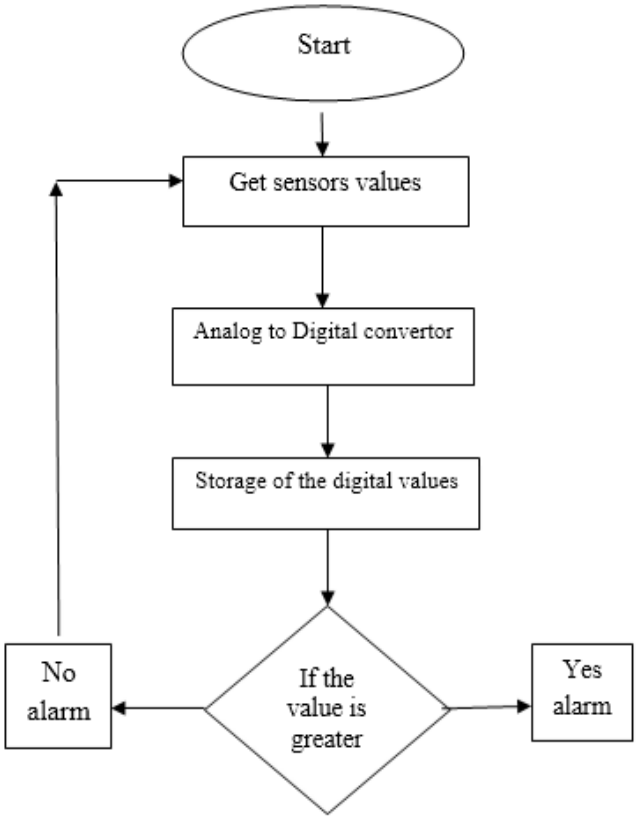

Fig 4: Flowchart for operation concept of the device

Circuit diagram of the device

The Figure 5 is showing the various connections to the component and input and output voltage of the device.

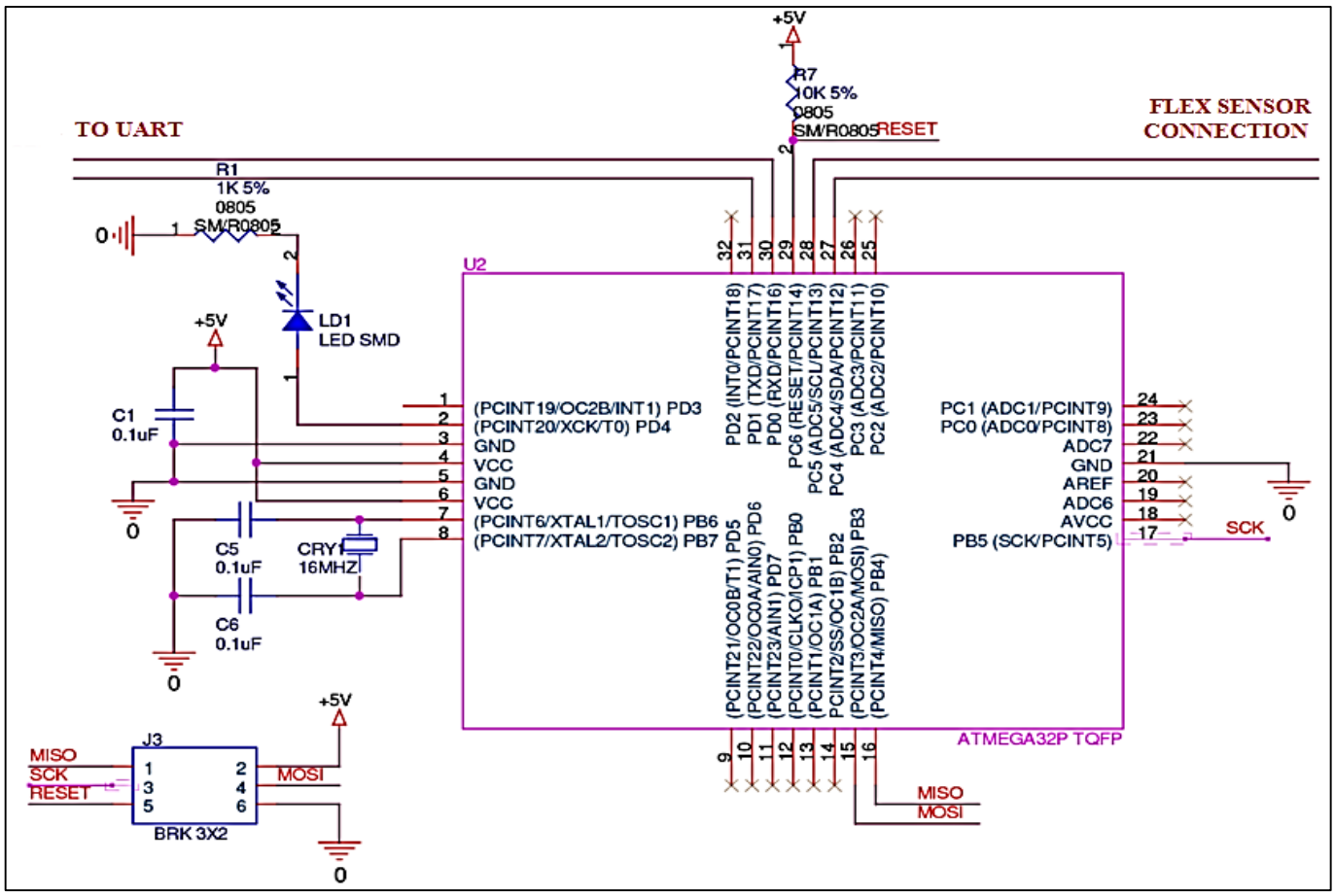

Fig 5: Circuit diagram of the device

Statistical tools

Statistical tools were applied in order to analyze the primary data gathered from the study. Z distribution and other inferential statistics were used to test the studied material to draw conclusions. The t test is one type of inferential statistics. It is used to determine whether there is a significant difference between the means of two groups. With all inferential statistics, it assumes that dependent variable fits a normal distribution. When it assumes a normal distribution exists, it can be identify the probability of a particular outcome. The level of probability is specified (alpha level, level of significance, p) a data is accept before we collect data when $p < 0.05$ is a common value that is used. After a data is collected a test statistic with a formula is calculated. A comparison of the test statistic is done with a critical value found on a table to see if the results fall within the acceptable level of probability. Modern computer programs and software are used to calculate the test statistic and also provide the exact probability of the test statistic value with the number of subjects we have. In test statistic a t test produces a t-value. Conceptually, t-values are an extension of z-scores depending on the number of sample used when the numbers of samples are up to 30. The test value is known as t-test value but when the samples are more than 30 the test value is known as z-test value.

Statistical analysis of samples using z-test distributions

Test for the significance and the correlation between the responds to scoliosis disorders by the application of the designed device on the various categories of human subjects by using t or z distribution statistics.

Responds is define in this research as positive and negative alarm of the buzzer.

Category is defined in this research as follows, male and female athletes, N in the table represents the total number of samples used.

Sig in the table represents the significant.

df represents the difference total sample before and the total sample after tor z test is calculated. It always has a value of difference of one.

Results and discussions

Table 1 is showing the number of young male athletes between the ages of 18 – 25 years who showed positive or negative to the buzzer alert device. The study was conducted on total of 30 human subjects young male athletes.

Table 1: Number of male athletes between the ages of 18 – 25 years who showed positive or negative to the buzzer alert device.

Subjects	Positive buzzer response	Negative buzzer response
1	Buzzer alert	-
2	Buzzer alert	-
3	Buzzer alert	-
4	-	No buzzer alert
5	-	No buzzer alert
6	-	No buzzer alert
7	-	No buzzer alert
8	-	No buzzer alert
9	Buzzer alert	-
10	Buzzer alert	-
11	-	No buzzer alert
12	Buzzer alert	-
13	Buzzer alert	-
14	Buzzer alert	-
15	-	No buzzer alert
16	Buzzer alert	-
17	Buzzer alert	-
18	-	No buzzer alert
19	-	No buzzer alert
20	Buzzer alert	-
21	-	No buzzer alert
22	-	No buzzer alert
23	-	No buzzer alert
24	Buzzer alert	-
25	-	No buzzer alert
26	-	No buzzer alert
27	-	No buzzer alert
28	Buzzer alert	-
29	-	No buzzer alert
30	-	No buzzer alert
Total	13	17

Table 1 and Figure 6 shows the statistics of young male athletes participants between ages 18 - 25 years who were tested with the buzzer alert device. It was found that 13 participants (constituting 43.30%) tested positive (i.e. Buzzer alert) while 17 participants (constituting 56.7%) tested negative (i.e. No Buzzer alert). The finding reveals the presence of spinal disorder in male athletes between the ages 18 - 25 years.

Table 2: Cumulative percentage of male athletes between the ages of 18 – 25 years who showed positive or negative to the buzzer alert device.

Buzzer alert	Frequency (No. of occurrence)	Percent	Cumulative percent
Positive	13	43.3	43.3
Negative	17	56.7	100.0
Total	30	100.0	

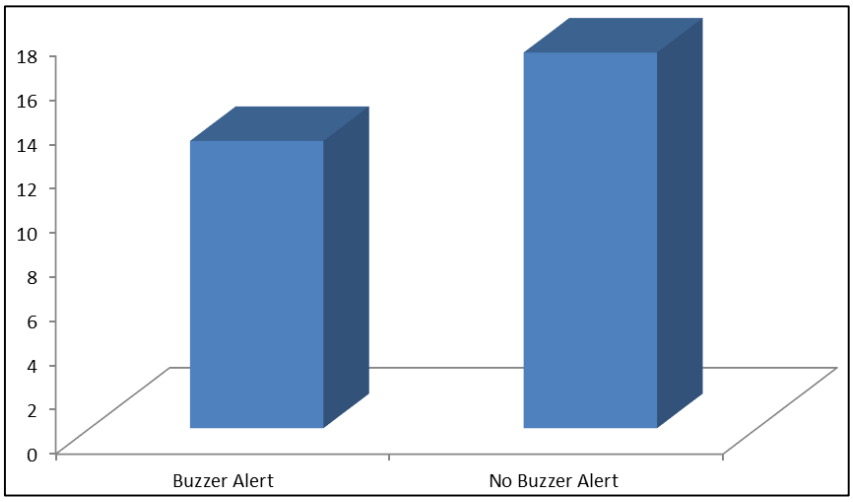

Fig 6: Bar chart showing the male athletes between the ages of 18 – 25 years tested with Buzzer alert device (x-axis: Buzzer alert; y-axis: Number of athlete)

Table 3: Number of young female athletes between the ages of 18 – 25 years who showed positive or negative to the buzzer alert device.

Subjects	Positive buzzer response	Negative buzzer response
1	-	No buzzer alert
2	Buzzer alert	-
3	-	No buzzer alert
4	-	No buzzer alert
5	-	No buzzer alert
6	-	No buzzer alert
7	Buzzer alert	-
8	-	No buzzer alert
9	Buzzer alert	-
10	-	No buzzer alert
11	Buzzer alert	-
12	Buzzer alert	-
13	-	No buzzer alert
14	-	No buzzer alert
15	-	No buzzer alert
16	Buzzer alert	-
17	Buzzer alert	-
18	-	No buzzer alert
19	-	No buzzer alert
20	-	No buzzer alert
21	Buzzer alert	-
22	-	No buzzer alert
23	-	No buzzer alert
24	-	No buzzer alert
25	-	No buzzer alert
26	Buzzer alert	-
27	-	No buzzer alert
28	Buzzer alert	-
29	Buzzer alert	-
30	Buzzer alert	-
Total	12	18

Table 4 and Figure 7 shows the statistics of young female athletes participants between ages 18 - 25 years who were tested with the buzzer alert device. It was found that 12 participants (constituting 40.0%) tested positive (i.e. Buzzer alert) while 18 participants (constituting 60.0%) tested negative (i.e. No buzzer alert). The finding reveals the presence of spinal disorder in female athletes between the ages 18 - 25 years.

Table 4: Cumulative percentage of female athletes between the ages of 18 – 25 years who showed positive or negative to the buzzer alert device.

Buzzer alert	Frequency (No. of occurrence)	Percent	Cumulative percent
Valid	12	40.0	40.0
No	18	60.0	100.0
Total	30	100.0	

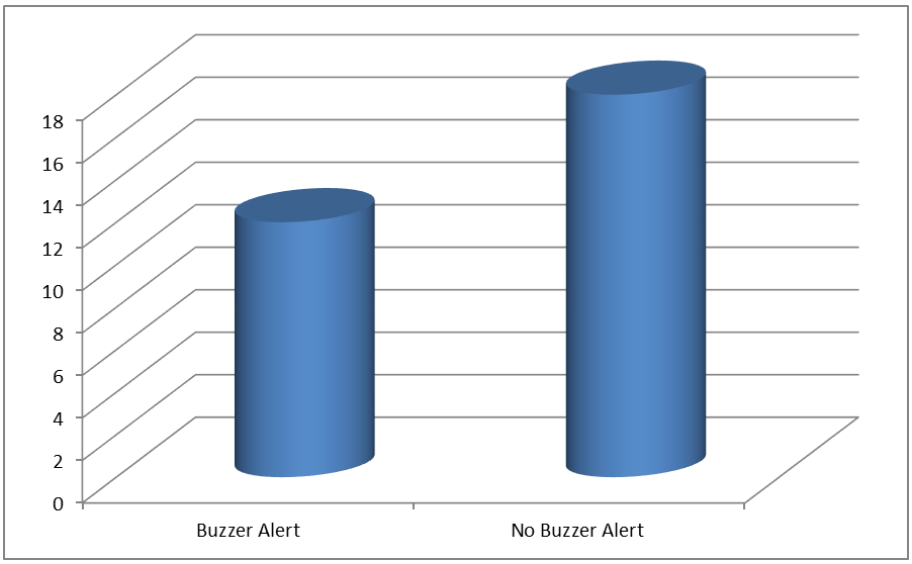

Fig 7: Bar chart showing the female athletes between the ages of 18 – 25 years tested with Buzzer alert device (x-axis: Buzzer alert; y-axis: Number of athletes)

Statistical analysis of samples using z - test distributions

Test for the significance and the correlation between the responds to scoliosis disorders by the application of the designed device on the various categories of human subjects by using t or z distribution statistics.

Table 5: Significance of two tailed test in z-distribution of young male athletes human subjects between the ages and response to the scoliosis device when tested on human subjects between the ages of 18 – 25 years.

Male athletes ages between 18-25years	Paired differences					Z	DF	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Age - Response	-.56667	.50401	.09202	-.75487	-.37847	-6.158	29	.000

The Table 5 shows the significance of two tailed test in t-distribution of male athletes human subjects between the ages of 18-25 years and their responses when tested with the scoliosis device. The 95% confidence interval shows that there is a significant or positive correlation between ages and responses of the human subjects between the ages of 18 – 25 years to scoliosis, because the significant value, 0.000 is less than 0.05.

Table 6: Significance of two tailed test in t-distribution of young female athlete shuman subjects between the ages and response to the scoliosis device when tested on human subjects.

Female athletes ages between 18-25years	Paired differences					Z	DF	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Age - Response	-.60000	.49827	.09097	-.78606	-.41394	-6.595	29	.000

The Table 6 shows the significance of two tailed test in t-distribution of young female athletes human subjects between the ages of 18-25 years and their responses when tested with the scoliosis device. The 95% confidence interval shows that there is a significant or positive correlation between ages and responses of the human subjects between the ages of 18 – 25 years to scoliosis, because the significant value, 0.000 is less than 0.05.

Schematic diagram of the complete device

The Figure 8 is showing the schematic diagram of the complete device with the various components attached of the spinal correction device.

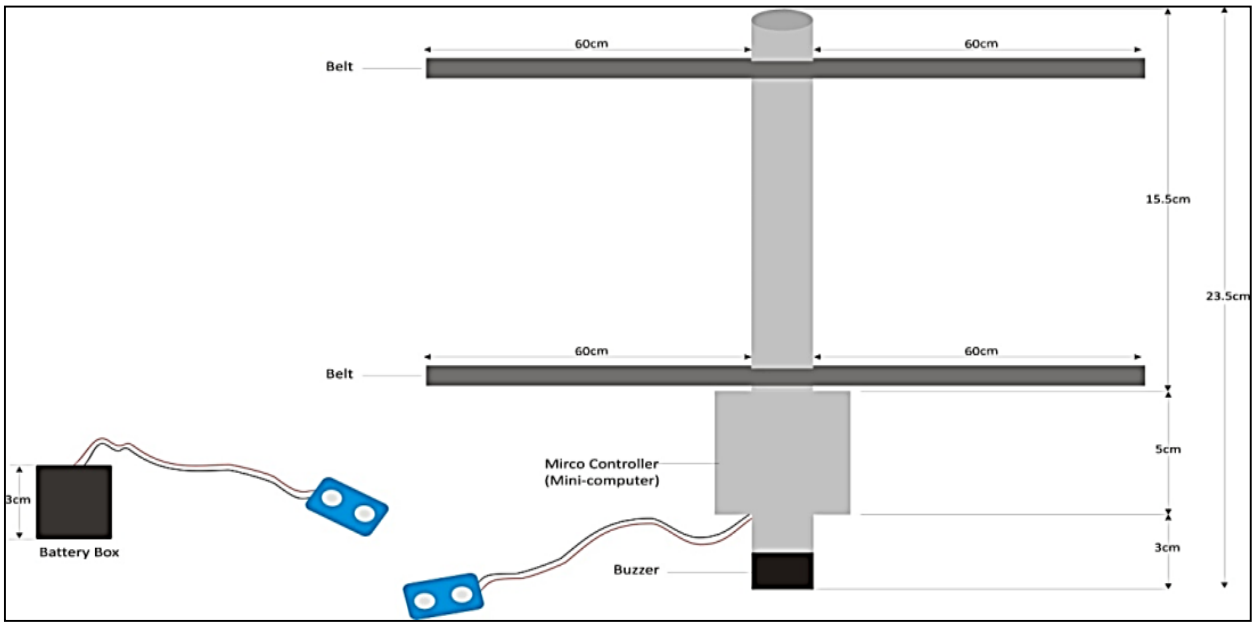

Fig 8: Schematic diagram of the spinal correction device.

Conclusion

Scoliosis which is, also said to be a genetically disorder disease is mostly acquired through various activities by the human subjects. Scoliosis is prevalence among most active group between 18-25 years young male and female athletes. The use of a very lighter, simple designed flexor sensor device with a buzzer was able detected early (mild and moderate levels) scoliosis, and to prevent severe form of scoliosis which will lead to surgery. The buzzer alarm system was in cooperated into the designed device to give a buzzer sound when the curvature is angle of human subjects is more than 10 degrees. Testing the device on human subjects who already have scoliosis with their x-rays images shows that the designed device is validatated. Using SPSS stastistical tool that's the t or z test for the analysis of the between the various categories and their responds to designed device its show a positive significance and high correlation of incident of scoliosis among young male and female athletes categories.

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