Study of the Efficiency of Electronic Postural Corrector in the Treatment and Prevention of Thoracic Hyperkyphosis in Children and Teenagers

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***Abstract* – In order to reduce postural problems in children and teenagers it was created an electronic postural corrector by the arduino technology that detects when the user is in an incorrect posture and warns him/her to behave properly. To ensure the efficiency of the device, this apparatus was tested on people with the problem of thoracic hyperkyphosis with the intuited to verify its efficiency regarding the treatment of this disease and on people who do not have the problem to verify its preventive efficiency. The test results prove the effectiveness of this equipment.**

Keywords: electronic postural corrector; arduino; treatment; prevention; thoracic hyperkyphosis.

I. INTRODUTION

Nowadays, the problems related to postural health are increasing considerably, it is because people do not take proper preventive care, and other natural factors. Often sedentary routine [1] and the bad habits related to excessive use of electronic devices [2] end up causing or contributing to problems like RSI's, scoliosis, hyperlordosis, hyperkyphosis, among others.

Problems related to bad posture are worrying because they start early, usually in childhood or adolescence, i.e., the stage at which they are developing, and they can worsen over time [1, 3]. The thoracic hyperkyphosis is one of them and it refers to an excessive curvature of the chest that can be developed through various factors such as malformation of the body structure, accidents and postural habits [4].

More specifically, the factors that may contribute to this postural problem, at this stage, is the attitude in the classroom where the child is sitting for several hours a day on his/her desk, and most often, inadequately and excessive weight in their backpacks [3]. One should also take into consideration the convenience offered by the technological resources that besides making them exercise less, they spend hours thumbing appliances, forgetting to behave in the proper posture [2]. This approach reflects the lack of knowledge and habits of people around the child in relation to postural health [5, 6].

In order to reduce this problem it is important to take precautions, since its inception, with preventive actions. There are several approaches to these actions. One of them is the physical exercise and social activities to make the child more active, with greater mobility and motor coordination. This practice has already been made for a long time and satisfactorily [1, 6], but not enough.

The child, most often, does not have the ability to police itself for proper posture, or even not worry about it. Then, it was created a device that assists in this matter. Such device is attached to the cloth through belt loops and it works by detecting that the user is in an unsuitable position and emits light vibration to alert him/her to return to the correct position.

To evaluate the efficiency of the electronic postural corrector, it was tested on a child and on a preadolescent in a period of one week during their daily activities. It was also done an evaluation after one week without using the device in order to verify if the absence it interfered on something. These people were chosen because one has the problem of thoracic hyperkyphosis, in which we verified whether there was improvement during the testing period and one that does not have this problem, to evaluate the preventive action of the device. At the end of this work the results will be presented in order to show the benefits or not that an electronic postural corrector can offer.

This article is divided into 5 sections. Further, part of the necessary theoretical basis for understanding the work is presented. In Sections III and IV are introduced the materials and methods and the obtained results by simulations. In section V are placed the final conclusions.

II. THEORETICAL FUNDAMENTATION

A. Thoracic Hyperkyphosis

The hyperkyphosis is the increase of curvature in the sagittal plane of the thoracic spine [4, 7, 8, 9], leaving the individual with shoulders thrown forward and rounded back [8, 10] that may be related to the increasing of size and weight of the breasts and chest fat [8].

It is a structural deformity, which may take the form of a long and rounded curve, or may be a localized posterior acute angulation, i.e., hump [4] (Figure 1). The postural deviation does not become merely an aesthetic problem. These failures can cause physical pain and [9] disability, besides respiratory diseases in some cases [11].

Fig. 1. Normal column and Hyperkyphosis

The main causes of hyperkyphosis are bad posture (juvenile curved back), neuromuscular problems, congenital defects (malformations), or inflammatory and post-trauma (fractures and osteoporosis), which alter the alignment of the bony, joint and muscle structures of the spine in its basic functions [12, 9, 11].

Postural dysfunctions of the thoracic spine are most frequently observed as the population becomes more sedentary, the symptoms are produced by bad positioning and lack of movement. This pathological spine deviation is evolutionary, showing a positive correlation between increasing age and increasing kyphosis [4].

The clinical diagnosis of hyperkyphosis is being complemented by radiographic examination and its treatment is directed usually to postural reeducation, muscle strengthening, orthotics in certain cases and in only exceptional cases surgical intervention [11].

The treatment is linked to the curvature angle of kyphosis. The normal kyphosis angle varies between 20 ° and 40 ° [10], values above 50 ° are considered as thoracic hyperkyphosis [9].

The radiographic examination is the most popular method of measuring hyperkyphosis, but a regular monitoring of the patient makes it injurious to health. For being a high cost and invasive method, there are other methods that do not expose people to radiation and are cheaper [7, 9]. Among the ones that exist, one can highlight the Flexicurve method.

B. Flexicurve Method

The Flexicurve is used to measure the curvature of the spine in the sagittal plane, being inexpensive, of quick review and noninvasive [7]

This method uses a flexible ruler called flexicurve (figure 2) where the professional with the aid of this apparatus measures the patient's kyphosis (on the skin) using the inches as the unit of measure. After obtaining the measures are entered in a worksheet followed by a formula (Table 1), the calculation is then made and displayed as a result the degree of curvature of the patient [7] column.

Fig. 2. Flexicurve ruler, used to measure Hyperkyphosis

```
=180/PI()*(ATAN(H*XTOTAL*(-3*XMEIO+2*XTOTAL)
/XMEIO/(XTOTAL^2+XMEIO^2-2*XTOTAL*XMEIO))-
ATAN(3*H*(XTOTAL-2*XMEIO)/XMEIO^2/
(XTOTAL^2+XMEIO^2-2*XTOTAL*XMEIO)*XTOTAL^2-
2*H* (XTOTAL^2-3*XMEIO^2)/XMEIO^2/
(XTOTAL^2+XMEIO^2-2*XTOTAL*XMEIO)*XTOTAL+
H*XTOTAL*(-3*XMEIO+2*XTOTAL)/
XMEIO/(XTOTAL^2+XMEIO^2-2*XTOTAL*XMEIO)))
```

Quadro 1. Required formula to achieve the degree of kyphosis.

If the obtained result with this formula exceeds 50º, it is concluded that the user has the Hyperkyphosis Thoracic.

III. MATERIALS AND METHODS

For the development of the work thinking about lower cost along smaller size, a prototype was designed based on the Arduino platform because this is Open Source, it has small, inexpensive equipment, and because of its broad community of developers and supporters. [13] The reason for the choice of the production of a small equipment is due to the fact that it will be attached to the clothing of the user and to the monitor into his/her daily routine

The following materials will be exposed in more detail and the methods that are used for the development of work.

A. Materials

The main components are: Arduino Pro Mini, flexure sensor (flex sensor) and the vibration motor (Vibracall), besides the 12V battery, a resistor of 1k, a voltage and wires regulator.

The Arduino is a board of prototype that aims to reduce costs and provides numerous opportunities for development [14]. There are several available models in the market and the chosen was the Arduino Pro Mini, because it is one of the nominees for wearable devices (wearable) and the prototype is intended to be coupled in robes user.

Besides being cheaper (an average cost around R$ 15.00) than conventional plates, it has its size reduced, measuring 1.8 cm by 3.3 cm and it offers greater ease in the connection of various points in a small or difficult fitting environment. It has a microcontroller based ATmega328 5V and 16 MHz [14] (Figure 3A). However, for the programming the board requires a connection with an FTDI module (Figure 3 B) for transmitting the code to the microcontroller [15]. Since it does not have an input/output USB as in other models of Arduino board.

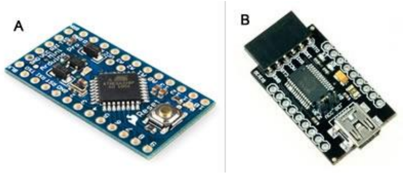

Fig. 3. Arduino Mini Pro (A) and FTDI module (B).

The flexion sensor, one of the main components of the prototype has the form of a flexible rod which detects the resistance applied by the scale produced, and there is a voltage following the same [13]. It works as a potentiometer. This sensor is attached to a device that is attached to garments to provide the degree of curvature of the user's spine determining the correct postural points (Figure 4).

Fig. 4. Flexion sensor.

The fact that this sensor measures only 4.5", approximately 11.4 centimeters, it does not make its use impractical since the prototype will be used in children and/or adolescents, besides that the smaller the equipment is, lighter and less uncomfortable the user will have.

Despite its size is lower than the flexicurve, it is noteworthy that for the calculation of kyphosis various points of the column are required, as for the detection of the improper curvature (via the flex sensor), the best point is the top of the column, in other words, the more critical point (where the greater curvature is).

The vibration motor, another main component of the prototype, is a vibracall commonly found in cellphones, consisting of half-cylinder which rotates on the motor shaft, with the rotation of the middle cylinder, purposely, it leaves the shaft with irregular weight, which causes the motor to move, and consequently with the rotation, vibration [16]. This process serves to warn of incorrect posture. The prototype was scheduled to intensify the vibration every time the posture is more incorrect (more curved) or soften when it is close to the appropriate point stopping to vibrate when he/she returns to the correct position (Figure 5a).

To unite all the components via the Arduino board it was used wires, common solder and to increase the strength, industrial hot glue.

The added components were: one 1K resistor (Figure 5 B) to stabilize the energy provided by the bending sensor and thus to obtain more accurate data by the spanning angle sensor; a voltage regulator (figure 5 C) for controlling the voltage supplied by the battery, allowing that different batteries are used by the device because it only accepts the 5V output (Model 7805). With this independent regulator of load provided above the allowed amount (5V) it will automatically adjust the voltage to the acceptable amount. This case was thought if it is necessary to use a more powerful battery for the device to work longer, in addition to a battery directly feeding the circuit could go miss its load and making at times the system did not work well, i.e. the motor could not vibrate properly as planned. There is still the problem of mismatch between the load components as 5V motor with batteries 3V, 6V or 9V even though having enough power it may not provide appropriate amperage or burn the equipment [17]; and, finally, a battery of 12V (Figure 5 D) to feed the equipment during testing.

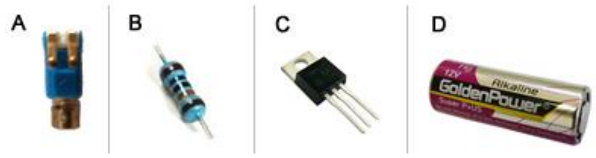

Fig.5. Vibracall (A), 1K Resistor (B), Voltage Regulator (c) and Battery (D)

B. Methods

As there are few materials (equipment) and the project itself is simple, the used method is also simple The aim would be to engage all equipment in an apparatus (Figure 6) that would be attached to the clothes of its user (Figure 7).

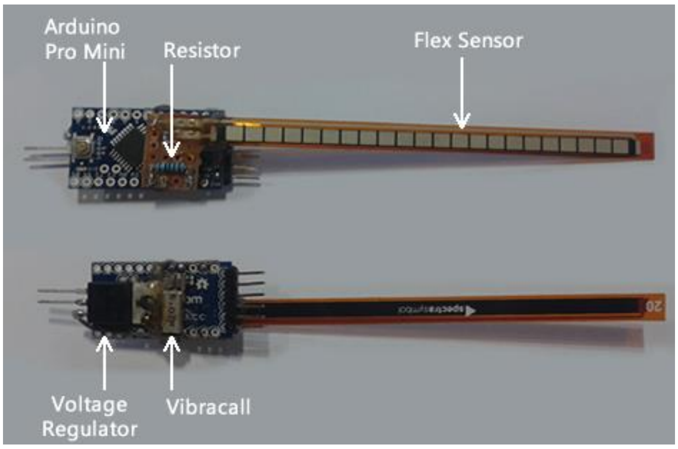

Fig. 6. Prototype of the Postural Electronic Corrector

Fig. 7. Using the prototype

The prototype has a bending sensor externally to establish contact with the spine of the user and to measure the degree of curvature. Thus, the microcontroller board Arduino Pro Mini triggers or not, depending on the measurement of the bending sensor, the motor vibration with the right intensity, thus alerting the user to keep up with proper posture..

To program the device it was used the Arduino IDE itself and for the logic, which is very simple, it was used three intervals on the degree of scale, that represents: little, medium and very worn and in accordance with the value received by the sensor bending vibration of the engine is started and paused (delay) following a given time, i.e., the more curved the lower will be the pause time of the vibrations, until the moment it will vibrate without interruptions (very worn). When the posture is properly without bending or with the minimum curvature the motor remains free of vibration.

The used code for programming the microcontroller Arduino board that has the function to receive the values of the bending sensor and the drive motor can be seen in figure 8.

```
int flexPin = A3;
int vibra = 2;
void setup() {
    pinMode(vibra, OUTPUT);
    Serial.begin(9600);
}
void loop(){
     if ((analogRead(flexPin) > 73) and (analogRead(flexPin) < 77)) {
            digitalWrite(vibra, HIGH);
            delay(500);
            digitalWrite(vibra, LOW);
            delay(500);
      }
      if ((analogRead(flexPin) > 77) and (analogRead(flexPin) < 80)) {
            digitalWrite(vibra, HIGH);
            delay(200);
            digitalWrite(vibra, LOW);
            delay(200);
      }
      if (analogRead(flexPin) > 80) {
            digitalWrite(vibra, HIGH);
      } else {
            digitalWrite(vibra, 0 );
      }
      Serial.println(analogRead(flexPin));
}
```

Fig. 8. Programming code used in the prototype.

To set these values to the motor drive tests it was performed tests in three people of varying heights in the presence of a physiotherapist, and it was found that with both of the value which the slope began to be unacceptable was approximately 77, based on that, it was created a range of values up 80, after this the curvature would be totally inadequate (at this point the engine vibrates uninterruptedly).

For the tests it was chosen an 8 year old female and a preadolescent male of 11 year old. Before using the equipment they went through a review by a physiotherapist that using the flexicurve method (Figure 9) found that the pre-teen has the thoracic kyphosis angle equal to 58.22 ° indicating a slight degree of thoracic hyperkyphosis, as the child has an angle of thoracic kyphosis of 39.50 º, i.e., he has the proper posture, since the amount of acceptable angle ranges between 20º to 40º becoming unacceptable from the 50º. Besides the child does not suffer from thoracic hyperkyphosis, she was subjected to the test by having tendency to acquire such a problem in future by the lack of guidance and also to verify the efficiency of the equipment as a preventive action.

Fig. 9. Application of the flexicurve method for evaluation.

After that both used the equipment during the period of a week in their daily routines, at different times, because there is only one machine available, making it impossible to test many people

First the pre-teen (Figure 10 A) used the prototype and then the child (Figure 10 B). The equipment was removed, along with the clothes, always when the volunteers developed activities that would preclude its use, such as bathing, sleeping and playing sports.

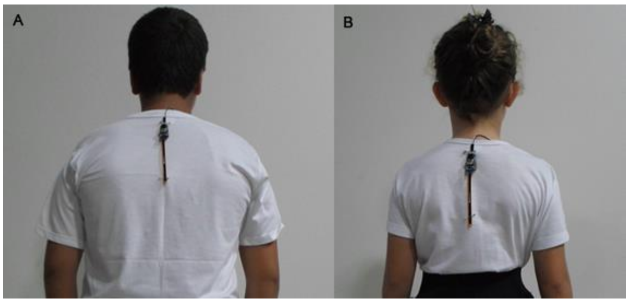

Fig. 10. Volunteers using the postural electronic corrector.

IV. RESULTS

According to tests, the results are satisfactory and can be observed that at the beginning of the evaluation the preadolescent showed 58.22 ° of thoracic kyphosis while the child had 39.5 °. Under the preadolescent to present a more severe condition the equipment was put into it first and after a week of use it was taken a new evaluation that showed a small improvement with 52.45 º, according to table 1.

Following the equipment was placed in the child to check the efficiency in the prevention and the outcomes after another week of use were minimal, with a new survey the thoracic kyphosis was scored at 37.97 º.

TABLE I - VALUES OF DEGREES OF THORACIC KYPHOSIS DURING TESTES

Users	**Beginning (before the use)**	**1st week (using)**	**2nd week (not using)**
Preadolescent	58,22º	52,45º	55,66º
Child	39,50º	37,97º	37,97º

Finally, it was make one more evaluation on the users in order to prove the efficiency of the equipment, where after a week without the use of an electronic postural corrector on the pre-teen the new thoracic kyphosis scored 55.66 °, i.e., a small increase (worsening) in the degree of kyphosis. Besides on the child, the value remained the same.

To better visualize the treatment and testing, the figure 11 shows a timeline for the level of kyphosis on both users on an evolutionary scale. Note the improvement of the pre-teen after the use and a worsening when not using the equipment. The child, for not having a high level, it shows a minimal but significant improvement for the documentation while using the equipment and while not using the equipment the degree of kyphosis remained the same.

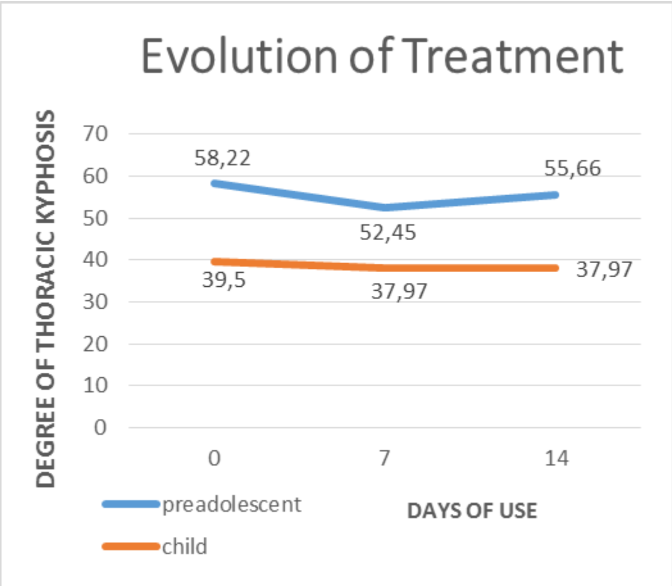

Fig. 11. Evolution of degrees of thoracic kyphosis on the users

CONCLUSION

This presented paper showed two strands of study, one focused on the use of Arduino technology in building an electronic postural corrector, and the other was to investigate the efficiency of the built equipment to solve the problem of bad posture in children and teenagers that can result in the development of thoracic hyperkyphosis.

For the construction of the equipment many technical details were studied in order to use the best devices assuming that the postural corrector should be cheap, light and small, i.e., causing the least possible inconvenience to the user. Beyond the technical part of building the equipment it was done studies to determine which points would be acceptable or not from the parameters of an ideal column span.

Taking into consideration that the equipment conforms to all the requirements for assessment of correct posture, it is concluded that the use of it in the volunteers was beneficial in both cases, both in the pre-teen, as in children, where in the first case was the kyphosis angle decreased, approaching the acceptable angle as he used the equipment and stop using such apparatus it returned to behave improperly, evaluating positively, in this case, the corrective action of the postural corrector. Since the child who did not have an unacceptable angulation had a small improvement, which also ensure a positive efficiency in the prevention of this problem.

Although the evaluation had been positive to the correction and prevention in these two cases, the corrector does not guarantee the efficiency of all users, depending on genetic issues or even more serious pathologies related to the column.

One can also observe that the efficiency of the device will only be guaranteed if such equipment is used properly. In tests, the users had all the necessary guidance of a physiotherapist, which indicated the correct positioning and the best way to use the equipment.

As future works, we intend to implement new studies in different situations, such as the use of equipment in more people and even, if necessary, for a period of time. In addition, applying it in diverse environments, such as the use of electronic postural corrector in classrooms where it would be linked to school uniforms and in software development companies, ie, places where people spend several hours sitting, without exercise and even move, prone to thoracic kyphosis.

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