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Smart Garment to Help Children Improve Posture

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Abstract – **Many of the aches and pains of adults are the result not of injuries, but of the long-term effects of distortions in posture or alignment. Postural kyphosis in adolescence may be one of the effects of poor standing and sitting habits. Kyphosis is an excessive rounding of the upper spine. A smart garment that can monitor and provide vibration feedback to children has been developed to investigate an alternative treatment possibility. Laboratory tests verified that the accuracy of the system was ±2° within the full 180° range. A clinical trial has been conducted and it showed that the system can aid subjects to improve by 20% the proportion of time in a more balanced posture. The long term effect is still under investigation.**

I. INTRODUCION

Many of the aches and pains of adults are the result not of injuries, but of the long-term effects of distortions in posture or alignment that have their origins in childhood or adolescence. If the posture, or body alignment, of a child or teenager is periodically examined and corrected throughout the growing years, that child will be far less likely to experience what we have come to accept as the customary aches and pains of middle and old age. On February 5, 2004 CTV news reported on "Computer posture a good lesson for children" that, "since more children are using computers these days, improper sitting may lead more and more children to suffer musculoskeletal injuries related to computer use. Children who play video games in front of a TV may have the same posture problems. The long term effects of repetitive strain injuries (RSI) on children are still unknown, but the impacts on spine or wrist development are sure." Ann-Kristina Arnold, an ergonomist, who teaches at Simon Fraser University also reported that, "anything repetitive, or with awkward posture is going to start to create some problems." It is believed that posture is a risk factor for some of the muscle strain injuries that you see. Harmful patterns of posture and movement can be traced to two factors: children's unconscious imitation of adults around them and the unintended effects of their early classroom experiences.

Postural kyphosis in adolescence may be one of the effects of poor standing and sitting habits in children. Kyphosis is an excessive rounding of the upper spine. Its treatment depends upon the severity, the age of the patient and the levels of the spine that are affected. Early diagnosis is a key to providing optimal treatment.

Kyphosis is a concave sever curvatures of the spine in the saggital plane. The most common cause for kyphosis is purely postural. Children stand in a hunched over position for a variety of non-physical reasons: it is easier, they may be self-conscious, they may have low self-esteem, or, in adolescent girls, they may slouch to hide developing breasts [1]. Poor posture usually worsens during the adolescent growth spurt, when a child may assume a more pronounced round back. Poor posture of this form, in which no underlying deformity or disease exists, is known as postural round back and usually is correctable. The diagnosis of postural round back can be made in two ways. First, determination of the flexibility of the spine - during examination the roundness corrects with hyperextension (bending backwards) or improvement of posture by the patient. When the child bends forward, a smooth gentle curve is seen, as opposed to a sharp peak as seen in Scheuermann's disease. The second way to diagnose postural round back is by ruling out other causes through radiographic examination.

The standard treatment for postural round back is education in proper sitting and standing. For children who continue to stand in a slouched position, an exercise program is the second stage of treatment. Exercises can strengthen the scapular muscles and spine extensor muscles. Typically, a physical therapist teaches an exercise regimen to the child and sets up a program for the patient to do at home. The therapist periodically meets with the child, to assure that the exercises continue to be performed properly. The sooner physical therapy is started, the less likely the child will end up with a lasting humpback deformity.

All of us have kyphosis to some extent, and curves as seen on radiographs of 20 to 50 degrees are considered normal [2] (Figure 1). For curves between 50 and 75 degrees, an exercise program is beneficial. Surgery will not generally be performed unless the curve goes beyond 75 degrees. A brace may be used if exercises are not effective in reducing the kyphosis. Bracing can be effective for kyphosis in the growing child if patients are compliant. However, the exercise program is labor intensive and the brace compliance is poor. An un-obtrusive self-teaching device may be a better way to provide an alternative treatment for kyphosis.

Many methods for human posture measurement have been developed, including goniometry, photogrammetry, optoelectric analysis, video analysis, sonic analysis etc. The principles of these methods have been summarized in Hsiao and Keyserling [3]. These methods have been widely used in the fields of orthopaedics and biomechanics, but most of them have the following disadvantages:

i) a laboratory environment is required,
ii) technicians are necessary to record data,
iii) analysis time is long, and
iv) the set up charge is expensive.

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This paper reports a “smart garment” to determine whether the biofeedback can benefit adolescents who have postural kyphosis.

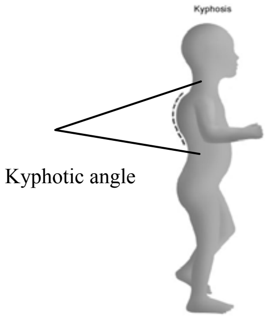


Figure 1. Kyphotic angle measurement.

II. MATERIALS AND METHODS

The smart garment consisted of a spandex type halter-top garment, two 3-axis accelerometers and a low-power small size wearable microcomputer. The size of the garment was customized to tightly fit the patient. Each garment consisted of three keyed pockets at which two for the sensors and one for the microcomputer. The locations of the sensors were chosen after a back image was taken or by suggestion from the patients’ physicians. Sensors were embedded into the pockets of the garment for comfort, security and ease of removal for laundering. After the sensors and the wearable computer were inserted into the pockets, no extra care was required. The 3-axis accelerometer (Freescale MMA7260Q) was chosen mainly because of its low-power, high sensitivity and small size. Figure 2 is the block diagram of the wearable microcomputer with the accelerometers.

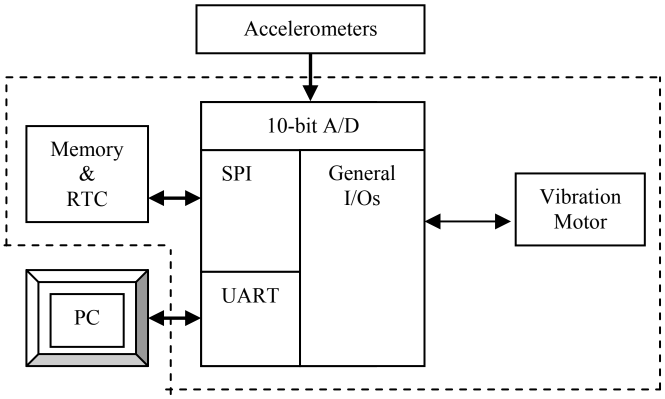


Figure 2. The block diagram of the wearable microcomputer with accelerometers.

A. Accelerometer

The size, weight and sensitivity of the accelerometer are 6mm x 6mm x 1.45mm, 2 grams and 727mV/g @ 3V, where g means gravity. When this accelerometer is used as a tilt sensor, the change of output voltage is the same as a sine function (most sensitive for small angles but less sensitive near 90^o). When the angle changes from 0 (zero g position) to 1 degree and from 85 to 90 degrees (1g position), the output voltage changes are 13mV and 3mV, respectively. In order to provide a higher accuracy in all measurements, a switching axis algorithm is used. Since the accelerometer is a 3-axis accelerometer, when one sensing axis of the sensor is near a 1g position, there is another sensing axis near a zero g position. Switching the measurement from one axis to the other improves the accuracy and resolution of the system. Figure 3 shows the output characteristics of the accelerometer at a 3.3V power supply with respect to different orientations [4].

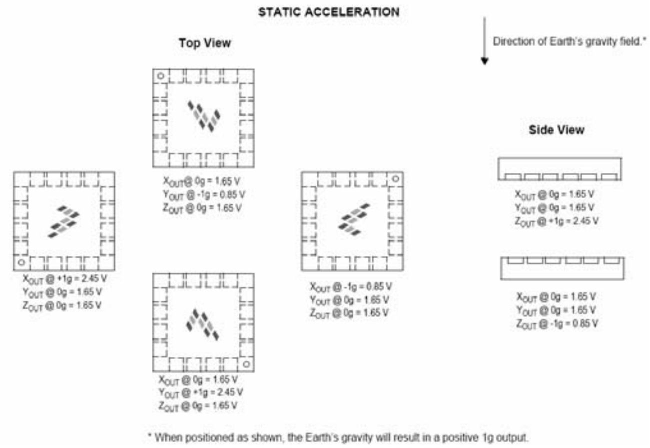


Figure 3. The output voltage of the sensing axis of the accelerometer with respect to different orientations at 3.3V.

B. The wearable computer

The size of the system is 5.5cm x 4.0cm x1.8cm, and its weight is 30g (Figure 4). The major component of the wearable microcomputer is the microcontroller, ATMEGA168L (Atmel Inc.). This microcontroller consumes very low power, has a built-in 10-bit analog-to-digital (A/D) converter and can be programmed to be in a very low power STOP mode in which it consumes 6μA. For the 10-bit A/D, the resolution of the system is 0.3 degrees and the error is ±0.3 degrees. This system also consists of a programmable real time clock (RTC) and a 1 Mbytes Flash memory. The RTC controls the sample duration and interval (range can be from 1 sample per second to 1 sample per day), and provides the necessary interrupts to the microcontroller. The memory can store up to 65536 samples. A lithium polymer rechargeable battery (3.7V, 200mAh, dimensions 31mm x 18mm x 6.9mm and 4.5 grams) was selected to minimize the weight and size of the system. A vibration motor, similar to a pager motor, was installed in the system. When the patient’s posture deviates from the target posture, a vibration feedback is provided. The length of the vibration feedback is increased when the patient does not correct the posture for a consecutive 3 minutes interval. In the best case scenario, when no feedback is activated during the entire study period and if the sample rate is 30 seconds per sample for 3 hours training session per day, the battery can last for 30 days without recharging and the memory can store 1 year of data. However, the longer or the more the vibration feedback is activated, the shorter the battery can be last before recharging. In the worst case scenario with the same configuration, the battery can only last 3 days. A one-hour recharging time is required to fully recover the battery. The charger is included with the system which does not require the removal of batteries.

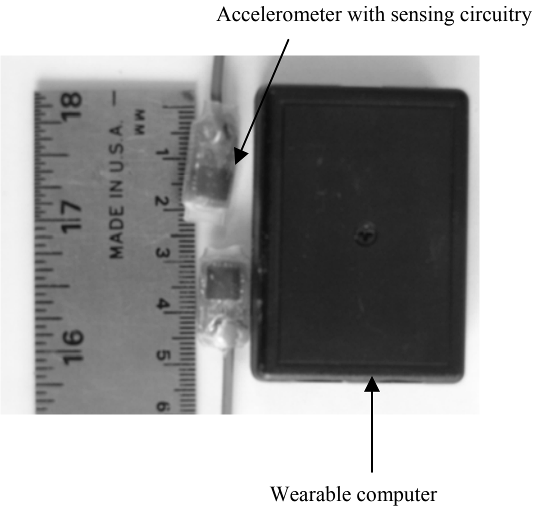


Figure 4. The wearable microcomputer and the accelerometer modules.

C. Laboratory Tests and Validation.

The system was tested in our laboratory before performing clinical trials. The laboratory set up is shown in Figure 5. The accelerometer was placed on a rotational disc with the system connected to a computer (Figure 5). The change of angle was measured with a protractor and with the system. The automatic switching axis algorithm was built inside the firmware. Three repeated measurements were performed.

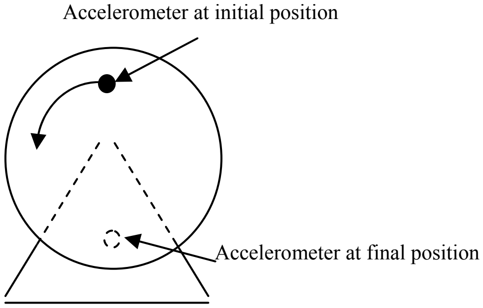
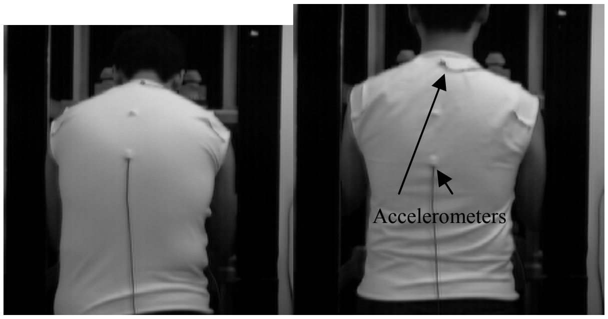


Figure 5. Laboratory test sets up.

A volunteer with no kyphosis then wore a smart garment performed two positions: a slough and a stand straight posture. A laser scanner, Minolta Vivid 700, was used to capture the back images (Figure 6). The Polygon Editing Tool^{TM} 2.0 software was used to measure the curved angle. The accuracy of the scanner system was ±1°. The location of the accelerometers was identified from the images. The measured curvature angle from the scanner system of the slough and stand straight positions were 59° and 32°, respectively. The kyphotic angles measured from the smart garment system were 57.9° and the 31.6°, respectively. The measured error was less than 2°.



(a) (b)

Figure 6a. Slouch position. 6b. Stand Straight position.

III. CLINICAL TRILAS

The same subject with no kyphosis volunteered to test the system for 2 days with 3 hours session per day. On the first day, there was no feedback provided. Feedback was provided on the second day while the measured angle was more than the personalized threshold value. Feedback was in the form of vibration (similar to a pager) for two seconds. For this study, the threshold was set 5° higher than normal standing. The sample rate was set at one sample per 30 seconds. The sampling rate was adjustable under software control and was set at a level that was not too frequent as to cause annoyance but often enough to make the subjects aware of their posture. During normal standing and sitting, this subject's kyphotic angle was 45.0 degrees. The first day data was used to estimate how many samples per day during the study session (3 hours) the subject would have posture deviated from the normal and the second day was to evaluate if the smart garment could alert the subject to maintain a more balanced posture.

A female adolescent, age 12.7, with thoracolumbar kyphosis was recruited from a scoliosis clinic. A written consent form was obtained before the laboratory measurements. Back shaped images were taken in a free standing and in an improved posture. The kyphotic angle at free standing and improved posture positions were 60° and 45° from the scanner system, 58.5° and 44.6° from the smart garment, respectively. The threshold value was set at the middle point of these positions, 51.5°. When the kyphotic angle is greater than 51.5°, a vibration feedback was provided. The data from this clinical trial has not been received yet.

IV. RESULTS

Figure 7 plots the calculated angles from the device versus the measured angles from a protractor. The result shows that the relationship of the two values is linear with $r^2 = 0.999$. The maximum error between the measured and the calculated angles is 1.6° with averaging of 3 measurements.

The result of the volunteer's trial is summarized in Figure 8. During the study period, the volunteer performed similar activities on both days: walking around the house and sitting in front of a computer. On day 1, the subjects had 192 samples at which the angle was greater than 50 degrees (the threshold value) (53% of the study time) while on day 2 he has 124 samples that were greater than the threshold (34% of the 3 hours study period). The subject improved by approximately 20% of the time to maintain a balanced posture.

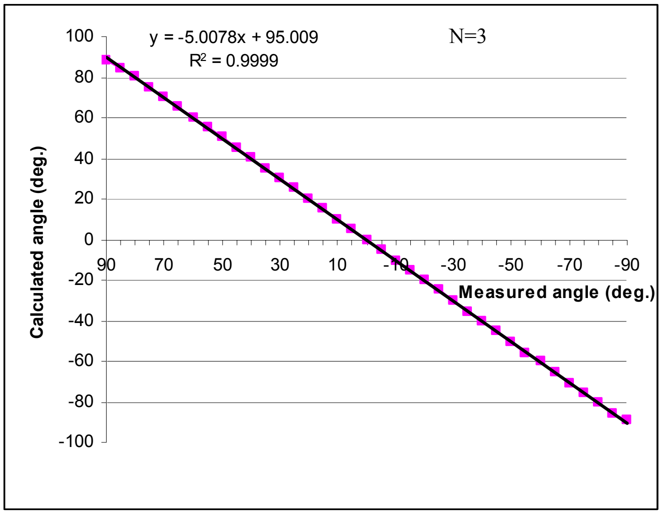


Figure 7. Averaged laboratory test results.

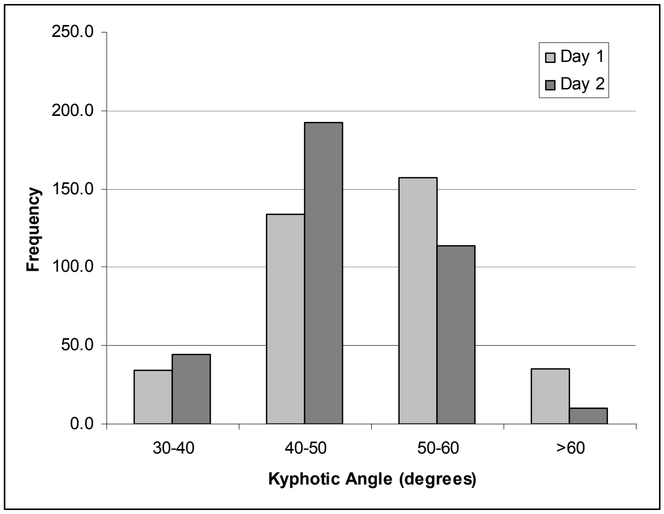


Figure 8. Volunteer test result.

V. DISCUSSION

This study is to apply the wearable computer to correct posture problems. Currently there is no commercially available garment that can monitor and provide feedback to children during daily activity. This approach is convenient. Children can train their postures anywhere and anytime. Children can put on the garment and set up the system instantly. Data are automatically saved into the computer system. The implementation of the smart garment may improve the posture of children who have mild kyphosis. Good posture is important because it helps your body function most efficiently. It promotes movement efficiency and endurance and contributes to an overall feeling of well-being. If you have poor posture, yours bones are not properly aligned, and your muscles, joints, and ligaments take more strain than nature intended. Faulty posture may cause fatigue, muscular strain, and in later stages, pain. Good posture also contributes to good appearance; the person with good posture projects poise, confidence and dignity.

V. CONCLUSION

A smart garment that can monitor human posture and provide feedback to alert a subject to maintain a more balanced posture has been developed. Measurement accuracy of this garment is ±2° within the full 180° range. The long term effect of this garment is still underinvestigation.

ACKNOWLEDGEMENT

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