# Collaborative, Social-networked Posture Training (CSPT) through Head-and-Neck Posture Monitoring and Biofeedbacks

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Keywords: Posture Training, Head and Neck Posture, Collaborative Training, Cloud Computing, Social Network, Peer-Influenced Learning.

Abstract: This research is motivated by the need of a tool to train elementary/middle-school students to maintain good posture while sitting. We propose a collaborative, social-networked approach to design the posture training tool so that students can be aware of and timely improve their bad posture. The posture training tool is composed of a wearable posture training headset, a social-network App, and cloud storage and computing services. The wearable training headset is equipped with real-time sensors to monitor head and neck postures. The App provides biofeedback mechanisms of sound, voice, or vibration, to remind the students when their postures become bad. In the App, students and their guardians can review the posture history and the statistical analysis of their postures. Students can glance over their friends' posture performance. Through this collaborative, social-networked approach, students of peer influences are thus encouraged to maintain good postures.

## 1 INTRODUCTION

Chiropractors and spinal specialists worldwide have seen an increase in the number of young patients experiencing "text neck" (Fishman 2017). Text neck and its syndrome are threatening to turn today's teenagers into a generation of hunchbacks. Originated by Dr. D. Fishman in Year 2008, the phrase "text neck" is to describe the repeated stress injury to the body caused by poor posture and brought on largely by overuse of all digital devices. Poor posture not only causes structural and spinal problems to people, but it can also lead to cognitive problems that may incur anxiety and depression (Pop, 2016), especially to those emotional and sensitive people like teenagers.

The rapid rise of poor posture in kids is the curse of modern era. Digitally savvy teens are likely the most affected because they use smartphones, tablets and computers the most. Moving the head forward and bending down in a hunched position for typing or gaming imposes high pressure in the spine. The pressure increases drastically with every degree of head/neck flexing. For head position of bending 45 degrees, the head exerts 22.5 Kg, comparing with 5.5 Kg in its normal position (Hansraj, 2014).

For older people, prolonged poor posture could result in permanent pains in their necks and shoulders, but the severity can be minimized for kids and adolescents through neck and shoulder stretches and exercise. Frequent breaks with simple neck and shoulder stretches can improve blood flow and relieve tension. Keeping good posture, with the body aligned in a neutral position, is the key to avoid straining the neck and shoulder. Posture awareness and timely improvement are important to stretch and relax the tense muscles.

However, actions always speak louder than words. It is not easy to deal with children on the brink of adolescent rebellion. Poor posture is not an immediate damage or hazard to people. Its harmful effects are not obvious and can only appear over a long period of time. Neck and shoulder pains may be annoying but texting or gaming are more attractive to teens.

Awareness of poor posture is not easy, not to say to do timely improvement to correct poor posture. Parents or teachers always exhort to sit or stand up straight, stop slouching and to straighten the shoulders. However, they cannot stay aside with kids all the time and most teens do not like so. The critical point is teens' self-awareness of their poor posture and the motivation to improve the poor posture.



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Parents and other significant adults may serve as important models in the childhood, but all become less effects when kids grow up. Adolescents are most influenced by their peers. They adopt or mimic many behaviors of their peers in some social settings in order to be accepted by their peers. Teens need encouragement and recognition from their peers. The imitation to peers can have positive or negative influences on teens, depending on several factors like what characteristics of the individuals is, how responsible the group members are, and so on. The influences can be strong or weak, heavily relying on the trust to each other and the competition among the peers of the group (Kirke, 2006; Lenhart et al, 2015).

The 21st-century-born teens are sometimes called the "*i-Generation*," representing the types of technologies, such as iPhone, iPod, iTune and Wii, being heralded by children and adolescents. They are digital natives, grow up with Internet connection, and are surrounded with technologies all days long. The Internet, mobile phones, and social network software all become an integral part of their lives and are increasingly relevant to their learning and social networking. While particular software websites may rise and fade, the *i-Generation* continue to engage through social network software for identity formation, status negation, and peer-to-peer sociality (Mason & Rennie, 2008).

The term *social network* refers to the web of social relationships that surround individuals (Heaney & Israel, 2008). In this research, it refers to the linkages between teens whose closeness is embedded in a informal group in which group members can provide social functions like emotional, instrumental, informational, and appraisal supports and collaboration to individuals. Social networks and social support can have positive effects on physical, mental, and social health (Ayubi et al, 2014). Collaborative social networks open up new ways to work with peers and improve engagement and effectiveness to activities (Webb, 1989).

This research aims to develop a tool to train elementary/middle-school students to maintain good posture while sitting. We propose a collaborative, social-networked approach to design the posture training tool, which is composed of a wearable, posture training headset, a social-network app (application program), and cloud storage and computing services. The wearable training headset is equipped with real-time sensors to monitor head and neck postures. An App is developed to provide biofeedback mechanisms of sound, voice, or vibration, to remind the students when their postures become bad. In the App, students and their guardians can review the history of posture and conduct statistical analysis of their postures. Some metrics are defined to indicate the behavior of their sitting postures. The App provides functions to glance over their friends' performance. Through the collaborative, social-networked sharing and competition, students of peer influences are thus encouraged to maintain their good postures.

The remainder of this paper is organized as follows. Section 2 proposes the design of the Collaborative, Social-networked, Posture Training (CSPT) framework. The posture training tool that adopts biofeedback techniques in helping correct poor head and neck posture is developed in Section 3. Section 4 presents the design of experiments to validate the effectiveness of collaborative, social-networked posture training. Section 5 discusses the experiment results. Finally, in Section 6 concluding remarks are made with some future research directions.

# 2 DESIGN OF COLLABORATIVE, SOCIAL-NETWORKED POSTURE TRAINING (CSPT) FRAMEWORK

Design of the Collaborative, Social-networked Posture Training (CSPT) framework is based on three technologies of (1) real-time, head-and-neck posture monitoring, (2) biofeedback mechanisms, and (3) social networks and collaboration. Monitoring of head and neck postures requires techniques of sensing the movement and measuring the displacement of head and neck positions in real time, with respect to their neural positions. Transformation among many coordinate systems is needed to reflect head and neck postures. Many researches have attempted to define the normal and correct posture of head, neck and shoulder, from various different points of view (Liao, 2016). Most researchers and practitioners adopt the idea along the neutral spine position — ears aligned with the shoulders and the shoulder blades retracted. This research uses head-and-neck angles — the angles between true vertical (or horizontal) and a line connecting C7 vertebra and tragus (the cartilaginous protrusion in front of the ear hole) as the head-and-neck posture.

The idea behind the biofeedback technology is that, by harnessing the power of the mind and becoming aware of what's going on inside the body, people can get more control over those normally involuntary functions. Biofeedback promotes relaxation and can help relieve a number of conditions that are related to stress.

Social connection and the quality of the relationships are important for physical health. The use of social networks and collaboration technology is appealing for three reasons. First, the *i-Generation* teens spend hours a day with their peers using social networks. Second, individuals can use social networks to share their performance in maintaining good posture to their peers. Third, peers give their appraisals and encouragement through social networks where positive social competition and support are timely and amplified. Collaboration among the peers is thus achieved.

The CSPT framework consists of posture monitoring wearables, handheld devices, a social-network app, and cloud storage and computing services. Its architecture is shown as Figure 1.

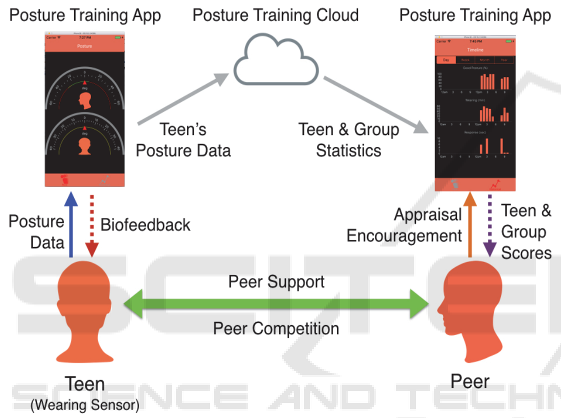


Figure 1: Architecture of the CSPT Framework.

The embedded-system-based device is devised to monitor neck-and-head posture in real time. Handheld devices like smartphones, and desktop or laptop computers are used to provide interface to the device. They also provide biofeedback and social networking functions.

# 3 BIOFEEDBACK POSTURE TRAINING TOOL

## 3.1 Biofeedback

Biofeedback is an autonomic feedback mechanism that gains awareness of physiological functions from the information measured by instruments (Schwartz & Andrasik, 2005; McKee, 2008). Biofeedback monitors and uses physiologic information (e.g. hearing, vision, feeling) to teach people to change specific physiologic functions (e.g., posture) accordingly. Figure 2 depicts the biofeedback mechanism in a posture control loop. In the control loop, posture is monitored and biofeedback to the sensory nervous system with sound, flashing light, or vibration in order to notify to change and improve the posture accordingly.

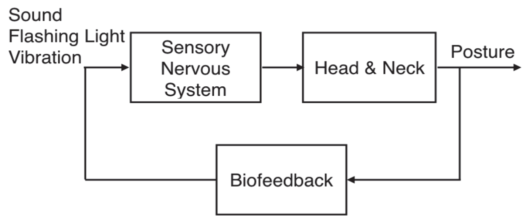


Figure 2: The Biofeedback Mechanism.

As one of the popular clinical therapy approaches in healthcare, biofeedback aims at helping people take responsibility for the cognitive, emotional, and behavioral changes needed to affect healthy physiologic change. A biofeedback mechanism includes both a biofeedback process and the instruments used in the process. A biofeedback process is a learning process where physiologic information is monitored and fed back through the biofeedback instruments. Biofeedback instruments monitor the physiologic processes, measure and transform the measurement data into auditory, visual, or vibrating signals in a simple, direct, and immediate way. The goal of biofeedback is to enable and change the physiologic process of the people, guided by the information provided by the biofeedback instruments.

Successful design of a biofeedback mechanism should consider the following factors:

- whether the individual have the capacity to respond;
- how the individual is motivated to learn;
- how the individual is positively reinforced to learn; and
- whether the individual is given accurate information about the results of the learning effort.

We design the biofeedback mechanism by using sounds, music, flashing light, and vibration functions of smartphones to timely notify the teens when their bad posture is detected.

## 3.2 Real-time Posture Training with Biofeedback

This research adopts the direct feedback learning mechanism that the individual gains control of the head and neck posture after receiving the feedback information. The biofeedback instruments monitor real-time head-and-neck posture and determine head craning forward or hanging downward. Using the biofeedback process with sound, light, or vibration, people receives alert or warning when their head and neck posture is determined as bad. The biofeedback mechanism guides the people to identify, change and correct the head and neck posture to right positions.

There are five steps in the operation scenarios of the CSPT system, described as follows:

1. *Initialization:* Teen wears the posture training headset and invokes the smartphone App.
2. *Monitoring:* The posture monitoring sensor continues to monitor the posture status and send streaming data to the receiving App or gadgets.
3. *Biofeedback:* The App or gadgets biofeedback to the teen with predefined sound, music, vibration, or flashing light, when poor posture is determined. The teen responds and corrects the head and neck posture to the good position timely.
4. *Storing and Analysis:* The posture data are compiled and transferred to the cloud for storing and further analysis. The teen can query and review their own historical behaviors and analytic information in their smartphone or smartwatch.
5. *Sharing and Research:* Notifications and analytic data can be shared to teen's parents, guardian, or friends. The data stored in the cloud, without violating privacy and security policies, can be shared to doctors, researchers, or public health workers to improve healthcare and welfare.

## 3.3 System Description

The CSPT system consists of three subsystems – Posture Monitoring subsystem, App subsystem, and Cloud Services subsystem. Each subsystem is described as below:

<u>Posture Monitoring Subsystem</u>

The Posture Monitoring subsystem is an embedded system with dedicated hardware of accelerometer functions to detect and transmit the 3-axis acceleration values of the device continuously. We adopt a 32-bit ARM Cortex M0 microprocessor ("Cortex-M0 Processor," 2017) as the core of the embedded system. The microprocessor equips with AES 128-bit encryption.

A 3-axis accelerometer of ultra-low-power, high-performance, MEMS (Micro-Electro Mechanical System) motion sensor is used in the embedded system to detect the attitude of the posture monitoring hardware, i.e., its pitch, roll, and yaw. Its function is to measure 3-axis accelerations with 16-bit data output rates in hundreds Hertz. The analog measured accelerometer readings are first converted into digital signals and then sent to the microprocessor via serial communication interfaces of I2C (Inter-Integrated Circuit) or SPI (Serial Peripheral Interface) to calculate the tilt angle of the posture monitoring hardware.

<u>App Subsystem</u>

The App subsystem plays many roles, from sensor data gateway and processing, biofeedback initiating, data feeder to the cloud, and presentation or rendering the historical and analytic posture information, to social networking GUI.

As the core in the App subsystem, the App executes and manages tasks of receiving, processing and further transmitting head-and-neck angles, determining to notify when biofeedback is needed, rendering the analytic data streams from the cloud, managing identity and access control, and doing encryption/decryption of the data and user ID, as the platform for chatting, messaging, and file sharing of social network functions.

Not every teen's smartphone is fresh and up-to-date. Some teens use parents' used smartphones whose OS or interfaces are unable to upgrade. Development of the App subsystem involves various and many smartphone models from different manufacturers with different OS and software versions and is so challenging and tedious as compared to the development of other subsystems.

<u>Cloud Services Subsystem</u>

The Cloud Services subsystem stores and syncs user data, exports the App analytic information, and supports social network services. We adopt the web services with the on-demand computing platform offered by a well-known Internet service provider that operates from 12 geographical regions across the world.

Several clustered servers are equipped in the cloud subsystem for web, applications and database server functions. NoSQL databases are adopted to manage user data, head-and-neck angles, and analytic data.

## 3.4 Wearable Training Headset

The wearable training headset is an earhook device that measures and transmits head-and-neck angles to the receiving smartphone. The wearable training headset is composed of four components, including accelerometer, microprocessor, power supply, and wearable earhooks and lanyard. Monitoring head-and-neck posture is accomplished by calculating head-and-neck posture angles, as described below.

In this research we adopts the C7-tragus angle, a.k.a. the cranial-vertebral angle, as depicted in Figure 3, as the metric to measure head-and-neck postures. A comfortable head-and-neck angle is about 30° in a normal sitting posture and about 40° in using computer. A posture below 25° or beyond 50° is considered poor and need-to-be-corrected.

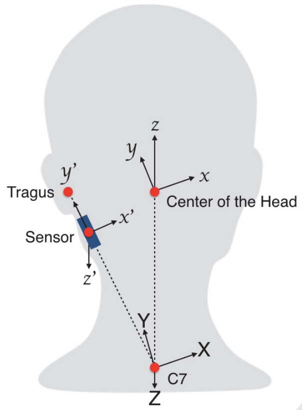


Figure 3: Coordinate Systems with Origins at C7, Sensor and Center of the Head, respectively.

Let $G = [\ G_{x'}\ G_{y'}\ G_{z'}\ ]^T$ be an acceleration vector, where $G_{x'}$, $G_{y'}$ and $G_{z'}$ represent the acceleration in x'-, y'- and z'-axis, respectively, and $G_{x'} G_{y'} G_{z'} \neq 0$. The tilt angle along the z'-axis, ρ, can be calculated by the following equation:

$$\rho = \cos^{-1}(G_{z'}/\mathrm{sqrt}(G^2_{x'} + G^2_{y'} + G^2_{z'})),$$

where $\cos^{-1}$(.) is inverse cosine and the sqrt(.) the square root functions, respectively. By measuring the amount of accelerations from the accelerometer, the above equation gives the angle how the sensor is tilted at with respect to the earth.

The tilt angle is further transformed into the people's coordinate system (x, y, z), with its origin at the center of the head in Figure 3. It is then converted into the posture angle. The stream of the posture angles forms a set of time-series data which are processed by the meta-heuristic based on Kalman filter and fuzzy logics algorithms (Dakhlallah, 2007).

The posture angle sensor is put in a find plastic enclosure that is attached to a lanyard and connects to an creative designed earhook in both sides. Figure 4 shows the wearable training headset.

Figure4: Wearable Training Headset.

### 3.5 Social Network App

As the core in the smartphone subsystem, the App is the only entrance for people to use the biofeedback system to prevent their neck and shoulder pains. The App provides registration function for new user to register in a simple step and start to use the system. It manages user identity and access control. The App is capable of doing encryption/decryption of the data and ID.

The App is a notifier for people to receive alert or warning so that they can correct the poor posture immediately. The App executes and manages tasks of receiving, processing and further transmitting head-and-neck angles, determining to play sound or music, or start vibrating when biofeedback is needed.

The App is also an important interface to people. It provides friendly GUI (Graphical User Interface) and renders the analytic data streams from the cloud. User can watch the status of their current head and neck posture and realize how good or poor their head and neck posture is. People can glance over their friends' posture performance. People can also query the analytic statistics of good posture (%), wearing time, and response time of historical data in different time scales spreading from day, week, month, to year. Figure 5 depicts an example of the analytic report in the day.

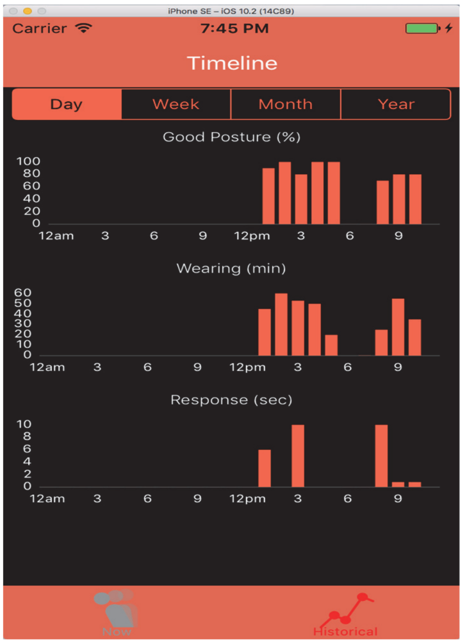


Figure 5: An Example GUI of the App.

# 4 DESIGN OF EXPERIMENTS

This section reports on the use of the proposed posture training framework with a group of six teenagers in a middle school in San Jose, California, U.S.A. The families in this group are similar in various respects, including their race of Asian Americans, socioeconomic status, occupational status, family size, housing, geographic location, ethics and morals. The teenagers are all 8th graders in the school and form peer ties. They study and play in very close proximity to each other of the group. They are denoted as "C", "E", "GC", "GW", "H" and "L", by the first letter(s) of their names, respectively.

## 4.1 Experiment Method

Our objectives in the design of experiments have four folds as follows:

1. to validate the effectiveness of the developed posture training tool;
2. to validate the effectiveness of the proposed CSPT framework;
3. to study the effects of peer influences on head-and-neck posture training; and
4. to study the effects of biofeedback on head-and-neck posture training.

The following three scenarios are designed for the experiments:

<u>Scenario I</u>

Both the Biofeedback and social network functions are DISABLED.

<u>Scenario II</u>

Biofeedback is ENABLED but social network function is DISABLED.

<u>Scenario III</u>

Both the biofeedback and social network functions are ENABLED.

The experiments were carried out in each teen's home during October 17th~21st and 24th~28th, Year 2016, with guidance of teens' parents. Each teenage is provided with a wearable training headset and the Posture Training App. They are asked to wear the training headset for at least sixty minutes a day. The experiments were carried out as follows: We tested Scenario I first in October 17th and 18th. The tests of Scenario II were followed in October 19th, 20th and 21st. And the tests of Scenario III in October 24th ~ 28th. The teens know nothing about the details of the three scenarios before the tests. That is, at first, the teens were told to wear the headset without knowing anything about biofeedback and social network functions for the first two days. They were aware of the biofeedback signals in Day 3 (October 19th). And on October 24th, they were told to download App's new function to glance at their friends' training scores. Before the experiments, all the teens knew who of their peers will participate the experiments. And they can share experiences and observations to each other during the test period.

## 4.2 Data Collection

Collection of the time-series posture data is achieved automatically via the wearable training headset, the App, and the Cloud services.

# 5 EXPERIMENT RESULTS

The effectiveness of the posture training tool and the proposed CSPT framework are deliberately reviewed and validated throughout the experiments. Tables 1 and 2 show the experiment results of good posture (%) and wearing time (min) of the six teens, respectively. and 2 show the experiment results of good posture (%) and wearing time (min) of the six teens, respectively.

Figure 6 depicts the comparison of average good posture percentages of Scenario I versus Scenario II, i.e., without versus with biofeedback. Note that the biofeedback does help increase good posture percentages of time for all the teens significantly. Similar results of biofeedback effectiveness on forward head posture have been observed and reported in the literature (Kim et al, 2011).

Results of good posture percentages of time (%) of each teen in Scenarios I, II and III are shown in Figure 7. Peer influences from teens' social network and social support do encourage teens in maintaining good posture. Same observations can be found in the results of wearing times. Figure 8 depicts the results of wearing times of each teen in Scenarios I, II & III, where peer competition and encouragement does urge longer wearing times in Scenario III, as compared to their wearing times in Scenarios I & II, respectively. In summary, through the collaborative, social-networked approach, the teens of peer influences are supported, encouraged, and collaborative to achieve the goals of maintaining good posture.

Table 1: Experiment Results of Good Posture (%).

| Date | Good Posture (%) | | | | | | Scenario |
|---|---|---|---|---|---|---|---|
| | C | E | GC | GW | H | L | |
| 10/17 | 65 | 85 | 80 | 78 | 74 | 87 | I |
| 10/18 | 68 | 88 | 82 | 76 | 77 | 85 | |
| 10/19 | 89 | 95 | 96 | 95 | 90 | 98 | II |
| 10/20 | 90 | 92 | 95 | 92 | 95 | 99 | |
| 10/21 | 85 | 95 | 90 | 93 | 92 | 98 | |
| 10/24 | 92 | 100 | 98 | 100 | 98 | 100 | III |
| 10/25 | 95 | 100 | 99 | 100 | 99 | 100 | |
| 10/26 | 94 | 100 | 100 | 99 | 100 | 100 | |
| 10/27 | 99 | 100 | 100 | 100 | 100 | 100 | |
| 10/28 | 99 | 100 | 99 | 100 | 100 | 100 | |

Table 2: Experiment Results of Wearing Time (min).

| Date | Wearing Time (min) | | | | | | Scenario |
|---|---|---|---|---|---|---|---|
| | C | E | GC | GW | H | L | |
| 10/17 | 60 | 61 | 60 | 63 | 61 | 74 | I |
| 10/18 | 61 | 64 | 60 | 62 | 61 | 77 | |
| 10/19 | 60 | 72 | 62 | 62 | 62 | 75 | II |
| 10/20 | 61 | 68 | 68 | 61 | 64 | 82 | |
| 10/21 | 61 | 69 | 65 | 60 | 61 | 86 | |
| 10/24 | 62 | 113 | 85 | 96 | 89 | 127 | III |
| 10/25 | 87 | 151 | 90 | 111 | 120 | 149 | |
| 10/26 | 102 | 155 | 121 | 160 | 158 | 156 | |
| 10/27 | 115 | 169 | 162 | 176 | 159 | 180 | |
| 10/28 | 152 | 192 | 170 | 179 | 167 | 190 | |

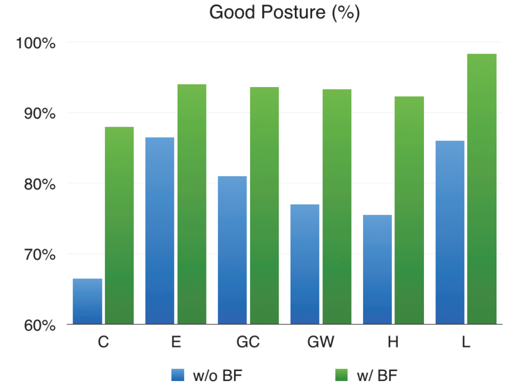


Figure 6: Results with vs. without Biofeedback (BF).

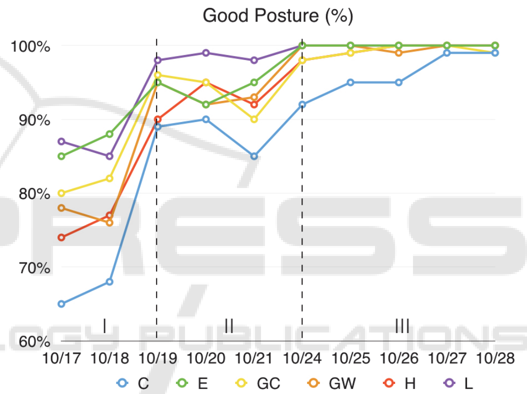


Figure 7: Results of Good Posture (%).

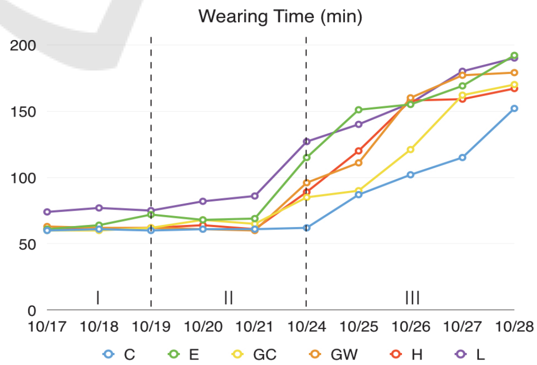


Figure 8. Results of Waiting Time (min).

## 6 CONCLUDING REMARKS

This paper develops a head-and-neck posture training tool to invoke students' awareness of their bad posture so that they can timely improve their poor posture and maintain good posture while sitting. A collaborative, social-networked approach is used and three technologies of real-time posture monitoring, biofeedback, and collaborative social networks are adopted, which consists of an embedded-system-based posture monitoring headset, a handheld device, a social-network App, and cloud services. The proposed framework is tested with a group of six middle-school best-friend teens for ten days. Three scenarios are designed to validate the effectiveness of the proposed approach and tools. Experiment results show that the proposed framework and the developed posture training tools are very effective in increasing teens' good posture percentage of time. Social support and peer influences are important and effective to encourage the peers in maintaining good posture and being willing to spend longer time in wearing the tool.

There are some mHealth apps, like iOS Health and Google Fit, and mobile wearable fitness devices available on the market. Only few of them have social networks or social media functions. There still needs an integrated social network platform to accommodate the bio-sensing functions for heart beats, EKG (electrocardiogram), blood glucose, and so on, as an integrated health service. Future research may consider the posture training of lower backs where disorders of the lumbar spinal and its surrounding muscle, nerves, bones, discs or tendons usually cause severe lower back pains due to poor posture.

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