Chapter 3

Collaborative, Social-Networked Posture Training with Posturing Monitoring and Biofeedback

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Additional information is available at the end of the chapter

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Abstract

This chapter presents an application of biofeedback techniques to train people to be aware of their bad posture to timely improve the posture. We design and develop a collaborative, social-networked posture training (CSPT) tool, which is composed of a sophisticated wearable posture training headset, a training belt, a social network App and cloud storage and computing services. The wearable posture training headset is equipped with real-time sensors to monitor head and neck posture. The training belt is used with a smartphone to monitor the lumbar-spine and low back posture. Biofeedbacks of sound, voice and vibration in the smartphone are sent to people to remind their poor posture. In the CSPT App, people can glance over their friends' posture performance to encourage good posture. Experiment results show that the proposed approach is very effective in increasing people's good posture percentage of time. Social support and peer influences are important and effective to encourage the people in maintaining good posture and in being willing to spend longer time in wearing the posture training tool.

Keywords: biofeedback, posture training, head and neck posture, lumbar and low-back posture, collaborative training, social network, peer-influenced learning

1. Introduction

This chapter aims to develop a biofeedback tool to train people, especially K-12 students, to maintain good posture while sitting. The rapid rise of poor posture in students—the curse of modern era has drawn more public attention recently due to their long-lasting use of smartphones, tablets and computers in head forward flexion postures. The phrase *text neck* [1] is invented to describe the repeated stress injury to the body caused by poor posture and brought on largely by overuse of all digital devices. Chiropractors and spinal specialists worldwide have seen an increase in the number of young patients experiencing text neck. Text neck and its syndrome are threatening to turn today's children into a generation of hunchbacks.

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 [2, 3], especially to those emotional and sensitive people like teenagers. Poor posture of 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. Digitally savvy teens are likely the most affected because they use smartphones, tablets and computers the most. For head position of bending 45 degrees, the head exerts 22.5 kg, comparing with 5.5 kg in its normal position [4]. Keeping a good posture with the body aligned in a neutral position is the key to avoid straining the body. Posture awareness and timely improvement are important to stretch and relax the tense muscles. In practice, it is not easy to aware poor posture, not to say to timely correct the poor posture.

Based on biomechanical measurements and measurements of the physiological systems of the body, biofeedback is the technique providing biological information to patients in real time that would otherwise be unknown [5]. The idea is to provide individuals with increased information about what is going on inside their bodies and brains. A close field called *cybernetics* [6] deals most directly with information processing and feedback, which makes learning possible. From a cybernetic perspective, individuals receive clear and direct biofeedback about their physiology which helps them learn to control the corresponding functions. Applications of biofeedback techniques can be traced back to the late 1950s, in the United States with the convergence of many disciplines [7]. Biofeedback methods have been used for more than six decades in rehabilitation to facilitate gait retraining [8]. The growth of biofeedback has been evolving with the development of new, more refined techniques for providing individuals with feedback for specific physiological processes.

Biofeedback devices have been used successfully in improving head control and balancing in children with cerebral palsy [9]. The investigation results on the effects of biofeedback on the sitting posture of a 14-year-old girl with cerebral palsy indicate a significant improvement in posture [10]. Breen et al. [11] develop a biofeedback system for real-time correction of neck posture in computer users. All the six subjects have a significant decrease in the percentage of time spent in bad posture when using biofeedback. Mirelman et al. [12] use an audio-biofeedback training system with headphones and successfully improve patients with Parkinson's disease from dysrhythmic and disturbed gait, impaired balance and decreased postural responses. Franco et al. [13] develop a smartphone-based system to monitor the trunk angular evolution during bipedal stance and help the user to improve balance through a configurable and integrated auditory-biofeedback loop.

Prolonged poor posture could cause permanent pains in neck and shoulder, especially for older people. However, for kids and adolescents, the severity can be reduced through proper exercise of neck and shoulder. Taking frequent breaks at work with neck and shoulder stretches can boost our productivity and also help improve blood flow and relieve tension.

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To avoid neck and shoulder straining, it is important to be aware of and timely improve the posture to keep the body aligned in a neutral position, that is, a good posture.

Furthermore, to know is one thing and to do is another thing. For children on the brink of adolescence, posture awareness and maintaining a good posture is more difficult to achieve. Texting and gaming are very interesting to teens. The effects caused by poor posture are neither obvious nor immediate to people. Their sequelae of annoying neck and shoulder pains can only appear over a long period of time. Parents and teachers can frequently remind kids to sit and stand up straight. However, they are unable to stay aside with children all the time, and most young people do not like so. Adolescents are most influenced by their friends and classmates. As the first generation of the twenty-first century, current teenagers were born into an entirely digital world. They grew up with Internet connection and have been surrounded with new technologies—mobile phones and social network software all days long. No matter good or bad, collaborative social networks have become an integral part of their lives and open up a new way with peers and improve engagement as well as effectiveness to their activities.

In the childhood, kids learn a lot from their parents and other significant adults. But their influences become less as children grow up. Peers become most influenced to adolescents who adopt or mimic many behaviors of their peers in some social settings in order to be accepted by their peers. Teenagers urge encouragement and recognition from their peers. Several factors like what characteristics of the individuals are, how responsible the group members are, and so on, may have positive or negative influences on teens' imitation to their peers. The influences whether they are strong or weak are heavily relied on teens' trust to each other and their competition among the peers of the group [14, 15].

The twenty-first century born teens, the "*i-Generation*," are digital natives. Their learning and social networking are all with the Internet, mobile phones and social network apps. While technologies and software websites may rise and fade, social network software still plays an important role in the *i-Generation* for their identity formation, status negation and peer-to-peer sociality [16].

In both ethnographic and empirical studies, it is commonly observed that the behavior of individuals is affected by that of their peers [17]. Group interactions are an important influence on individual decisions. In education, the returns to programs such as athletics and art cannot be measured simply by their direct effects on grade points. The participation and group interactions among students are also important earnings. With harmonious social relations, academic achievement may be easy to attain, even in schools in the most disadvantaged neighborhoods.

Some researchers have conducted experiments in which subjects receive information about others' choices [18, 19]. In these experiments, a subject's choice depends on both subject's preference as well as others' choices. Brechwald and Prinstein [20] review empirical and theoretical contributions to a multidisciplinary understanding of peer influence processes in adolescence over the past decade. They identify five themes of peer influence research, including behaviors relevant to peer influence, peer influence mechanisms, peer influence moderators, integration of behavioral genetics, neuroscience and peer influence research. While most previous research emphasize on the dynamic, reciprocal associations between selection and socialization in adolescent peer relations, their review focuses predominantly on their socialization processes as the mechanisms in the past decade have continued to vary considerably due to new mobile and social network technologies.

It is difficult to detect and measure peer effects precisely. Peer effects are the average intra-group external effects which are identical on all the members of a given group. Due to the disaggregation and availability of data, the group boundaries for such peer effects are often random and varying. Calvó-Armengol et al. [21] propose a peer-effect model to relate analytically equilibrium behavior to network location. Their results show that the outcome of each individual embedded in a network is proportional to her Katz-Bonacich centrality measure [22, 23] at the Nash equilibrium. For each individual, the Katz-Bonacich centrality measure considers both her direct and indirect friends but puts less weight to her distant friends.

The term *social network* refers to the web of social relationships that surround individuals [24, 25]. Social networks are a social structure of nodes that represent individuals and the relationships between them within a certain domain. This research adopts social networks as the linkages between students. The closeness of students is embedded in an informal group where group members can provide social functions like informational, instrumental, emotional and appraisal supports to individuals. Social supports and collaboration can be very constructive to physical, mental and social health of individuals. The wide use of smartphones and social networking apps offer opportunities for the development of innovative interventions to promote physical activity. Ayubi et al. [26] develop a persuasive and social mHealth application designed to monitor and motivate users to walk more every day. Collaborative social networks open up new ways to work with peers and improve engagement and effectiveness to activities [27].

Publics, where norms are set and reinforced, play a crucial role in the development of individuals. However, society's norms and rules only provide the collectively imagined boundaries. People, especially teenagers, learn through action, not just theory. They are also tasked with deciding how they want to fit into the structures that society provides. Their social identity is partially defined by themselves and partially defined by others. The answer to why students joined social network sites is usually simple: "That's where my friends are." The rapid adoption of social network sites by teenagers in the United States and in many other countries around the world has drawn much research attention [28]. Centola [29] studied the spread of health behaviors through artificially structured online communities and the effects of network structure on diffusion. His research reveals that when participants receive social reinforcement from multiple neighbors in the social network, individual adoption is much more likely.

Social presence is shown to have an effect in different virtual learning environments [30]. Liccardi et al. demonstrated the social dimensions of a collaborative learning network, its formation, its presence and its influence on different social networks in education [31]. They found that group composition may affect how efficiently a group achieves its set goals. It is optimal that there are both goal-oriented group members and socially oriented people within the same network. Both are needed in order for a group to achieve its goals as well as experiencing the group as socially rewarding.

This chapter presents the research that uses biofeedback techniques to train people to be aware of their bad posture to timely improve the posture. We develop a collaborative, social-networked posture training tool which is composed of a wearable posture training headset, a posture training belt, 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 posture. The training belt is used with a smartphone to monitor the lumbar-spine and low back posture. The App provides biofeedbacks of sound, voice and vibration to remind students of their poor posture. In the App, students can glance over their friends' posture performance to encourage good posture.

This chapter is organized as follows. Section 1 describes the motivation and identifies the importance and challenges of this research. In Section 2, we present the techniques of posture training with biofeedback. Section 3 proposes the collaborative, social-networked posture training (CSPT) approach. Section 4 details the systematic design and integration of the developed posture training system. Section 5 presents the design of experiments to validate the effectiveness of collaborative, social-networked posture training. Experiment results are analyzed in Section 6. Finally, in Section 7, the concluding remarks are made with some future research directions.

2. Posture training with biofeedback

2.1. Biofeedback

Biofeedback is an autonomic feedback mechanism that gains awareness of physiological functions from the information measured by instruments [32]. Biofeedback monitors and uses physiologic information (e.g., hearing, vision, feeling) to teach people to change specific physiologic functions (e.g., posture) accordingly. A biofeedback mechanism involves measuring biomedical variables and relaying them to the user using either direct feedback regarding the measured variables with a numerical value displayed, or transformed feedback where the measured variables are transformed into an adaptive auditory signal, visual display or tactile feedback method. The majority of biofeedback therapy has focused on the treatment of upper limb and lower limb motor deficits in neurological disorders.

Figure 1 depicts the biofeedback posture training loop, where head, neck and lower back posture is monitored and biofeedback to the human sensory nervous system with sound, light and vibration in order to notify the people to improve her head, neck and lower back posture accordingly. In the biofeedback process, posture signals are first measured by sensory and filtering devices where filtered sensor data are generated and sent to posture estimator to construct the corresponding posture angles. The posture angles are used by fuzzy logic trainer to diagnose the posture and determine what alters (sound, light, or vibration) to biofeedback to the human sensor nervous system.

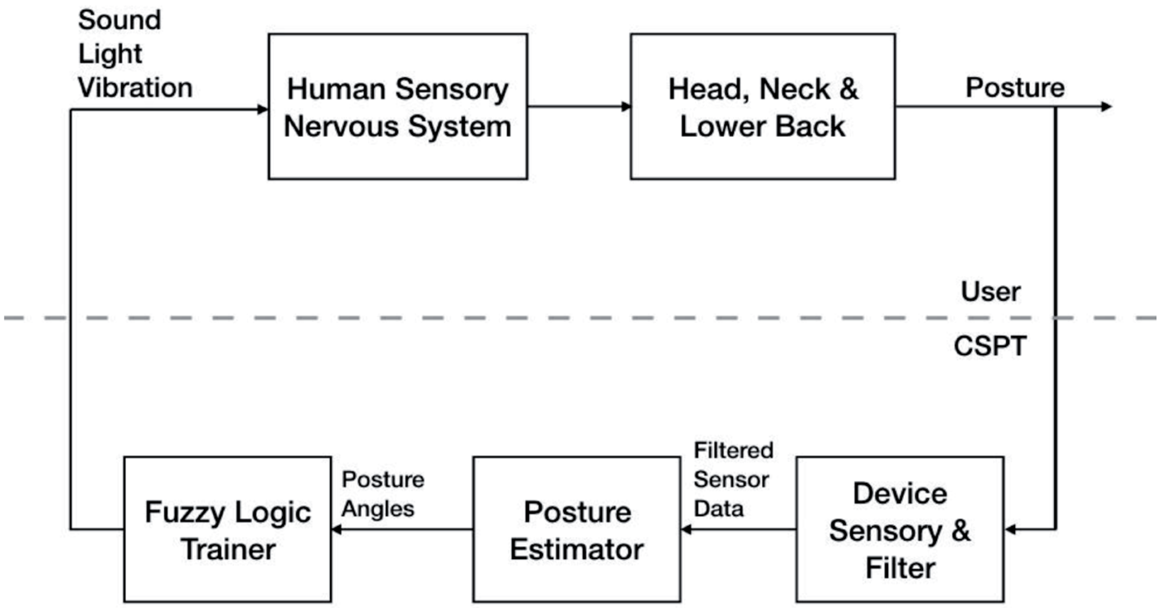

Figure 1. The CSPT biofeedback posture training loop.

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

A well-designed biofeedback mechanism should consider the following conditions:

- whether the individual is capable of responding;
- how the individual is inspired to learn;
- how the individual is encouraged to learn; and
- whether the individual is given correct information about the results of the learning effort.

In this chapter, we adopt sounds, music, flashing light and vibration functions of smartphones in design of our biofeedback mechanism so that teens can receive timely notations when their bad posture is detected.

2.2. Posture monitoring

The purpose of posture training is to keep the body at its *neural* position. Several attempts have been made to define neutral of the head/neck and lumbar/low-back regions [33–42].

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Many physiological landmarks such as tragus, canthus, eye socket, nation, or infraorbital notch have been used in measuring head/neck posture. Sitting is a common aggravating factor in neck, shoulder and low-back pains. Head/neck posture and cervical flexion are a complicated mechanism involving the skull and eight joints of C1 through T1 vertebrae. The head/neck angle often referred to as the degree of forward or peering head posture, or neck protraction is typically defined as the angle between vertical and a line connecting C7, T1, or the acromion to various skull landmarks. The C6-C7 vertebrae are important because they support and stabilize the head during its movement. When people sit in a good posture, the line of gravity should pass through the C6-C7 vertebrae. The C7-tragus angle, also known as the cranial-vertebral angle, is the angle between a vertical line passing through C7 and the line from C7 to the tragus. The lumbar angle (T10-L3 and L3-S2) [38] is typically defined to measure the ability to reliably position people into a neutral lumbar spine sitting posture.

In a study comfortable head and neck posture at computer workstations, Ankrum and Nemeth [43] suggested that the mean observed head tilt (Ear-Eye Line 7.7° above horizontal) and head/neck posture of 43.7° in C7-tragus against vertical are more flexed. Breen et al. [11] measure head and neck angle by placing an accelerometer device at the C7 vertebrae directly, as measuring the cranial-vertebral angle.

As the state of head/neck posture is unobservable, in this research, we adopt the C7-tragus and L3-S2 angle, as the metrics to measure head-and-neck and lumbar postures, respectively, as depicted in **Figure 2**. 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. A comfortable lumbar angle is about 5° in normal sitting posture. A posture below 0° or beyond 15° is considered bad.

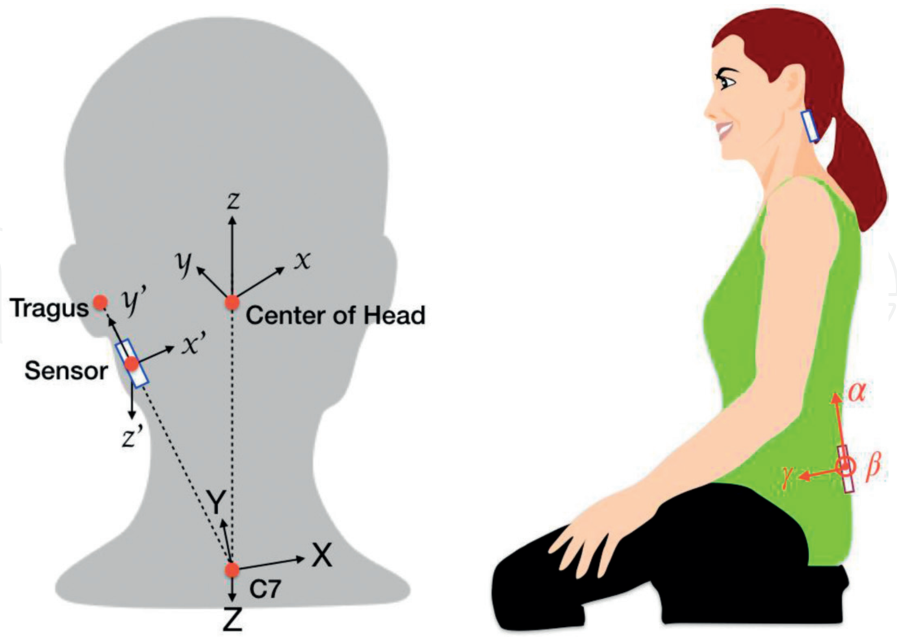

Figure 2. Posture monitoring (left: head/neck, right: lumbar/low back).

Figure 3. Posture training devices (left: head/neck training headset, right: lumbar training belt).

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:

$$\rho = \cos^{-1}\left(\frac{G_{z'}}{\sqrt{G_{x'}^2 + G_{y'}^2 + G_{z'}^2}}\right) \tag{1}$$

With the accelerations measured and provided by the accelerometer, Eq. (1) can calculate the tilt angle of the sensor with respect to the earth.

The calculated tilt angle needs to be further transformed into the coordinate system (x, y, z) of the head, with its origin at the center of the head in **Figure 1**. The sensor tilt angle is then converted into the head/neck posture angle. The lumbar angle can be determined along similar calculations. 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 [44]. Rather than placing an accelerometer in the C7 vertebral only such as in [11], our innovative design puts the posture angle sensor along with the C7-tragus line. The posture angle sensor is fixed with a fine plastic enclosure that is attached to a lanyard and connects to a creatively designed earhook in both sides of the ears. **Figure 3** shows the wearable training headset.

3. Collaborative, social-networked posture training

This research adopts the direct biofeedback learning mechanism that the individual gains control of the head and neck posture after receiving the biofeedback. Our biofeedback sensing and filtering device monitors real-time head/neck and lumbar posture and determines head craning forward or hanging downward as well as the forward low back. Using the biofeedback process with sound, light, or vibration, people receive alert and warning when their head/neck or lumbar posture is determined as bad. The biofeedback mechanism guides the people to identify, change and correct the head/neck or lumbar posture to right positions.

Operation scenarios of the collaborative, social-networked posture training (CSPT) system are summarized into the following five stages: *Preparation*, *Measuring*, *Posture Control*, *Analysis* and *Sharing*, whose details are described as follows:

Stage 1. *Preparation*.

A subject wears the posture training headset and the lumbar belt, invokes the CSPT App and places the smartphone in the lumbar belt.

Stage 2. *Measuring.*

The posture monitoring sensors start to monitor the posture status and send streaming data of posture angles to the receiving CSPT App or gadgets.

Stage 3. *Posture Control.*

The App or gadgets biofeedback to the subject with sound, music, vibration, or flashing light, when poor posture is determined. The subject responds and corrects the head/neck or lower back postures to the good positions timely.

Stage 4. *Analysis.*

Posture data are compiled, transferred and stored in the cloud for further analysis. The subject can query and review their own historical behaviors and analytic information in their smartphone or smartwatch.

Stage 5. *Sharing.*

Notifications of posture alerts and analytic data can be shared to subject's parents, guardian, or friends. Without violating privacy and security considerations, the data and analytics stored in the cloud can be shared to doctors, researchers, or public health workers to improve healthcare and welfare.

The collaborative, social-networked posture training (CSPT) framework is designed and based on three fundamental technologies of (1) real-time posture measuring, (2) biofeedback control and (3) social networks and collaboration. Monitoring and measuring of head/neck and lower back postures require techniques of sensing the movement and measuring the displacement of head/neck and lumbar positions in real time, with respect to their neural positions. Transformation among many coordinate systems is needed to reflect head/neck and lower back postures.

There have been some researches attempting to define the normal and correct posture of head, neck and shoulder, from various different points of view [45–47]. The idea along the neutral spine position—ears aligned with the shoulders and the shoulder blades retracted—is mostly used by many researchers and practitioners. This research defines the head/neck posture by the head-and-neck angle—the angle between true vertical (or horizontal) and a line connecting C7 vertebra and tragus (the cartilaginous protrusion in front of the ear hole). This research also defines the lumbar posture by the lumbar angle—the angle between true vertical and a line connecting L3, the middle of the five lumbar vertebrae and S2 at the level of posterior superior lilac spine. Both the head-and-neck and lumbar angles are measurable (or *observable* in the control theory context). We use both the head-and-neck angle and the lumbar angle to model the upper-body posture. The determination of a good posture depends on a series of sophisticated transformation and computation with the fuzzy logic combination of head-and-neck and lumbar angles. When a bad posture is detected and lasts for a short period of time, the biofeedback mechanism starts to send alerts and notifications to the wearing kid to adjust and restore to a good posture.

Biofeedback technology is based on the idea that people can get more control over those normally involuntary functions by harnessing the power of the mind and becoming aware of what is going on inside the body. Biofeedback facilitates relaxation. It can help relieve several mental and physical conditions that are related to stress. The posture training CSPT App provides biofeedbacks via sound, music, voice and vibration to remind teenagers of their poor posture.

Social connections—both quantity and quality—are crucial to mental and physical health. The reasons that we adopt social networks and collaboration technology to encourage posture training of teens have three folds: first, Internet users, especially *i-Generation*, are now spending several hours per day with their peers on social media platforms. Second, information sharing has become an indispensable part and is more dynamic and more connected in social media revolution. Social networks platforms make it easy for teens to share their experience and performance of their maintaining good posture to their peers. Third, teens interact with their peers and receive appraisals and encouragement from their friends through social networks so that positive social support and competition are timely and reinforced. Posture training and collaboration among the teens is thus achieved.

As depicted in **Figure 4**, the CSPT framework consists of four building modules—posture monitoring wearables of posture training headset and lumbar belt, a smartphone, a social network CSPT App and CSPT cloud services. A posture monitoring device implemented with an embedded posture-sensing system is devised to monitor the neck-and-head posture in real time. A smartphone is used to provide interface to the device. A special-design lumbar belt is used to hold the smartphone so that the low back posture can be properly measured. While the subject wears the posture monitoring wearables, the corresponding posture data are filtered, streamed and sent to the CSPT App for posture estimation and determination. Once a bad posture is determined, the CSPT App sends biofeedback signals of sound, music, flashing light, or vibrations to notify the wearing kids to adjust and improve their posture timely. User's posture data are sent to the CSPT cloud for storage and further processing. The statistics and analytics of posture behaviors by individuals and groups are provided by CSPT cloud computing. Teens as well as their parents, teachers and friends can overview these posture behaviors in the CSPT App, including peers' appraisals and encouragements. Strong and interesting engagement to posture training activities can be established and continue via good peer support and positive peer competition.

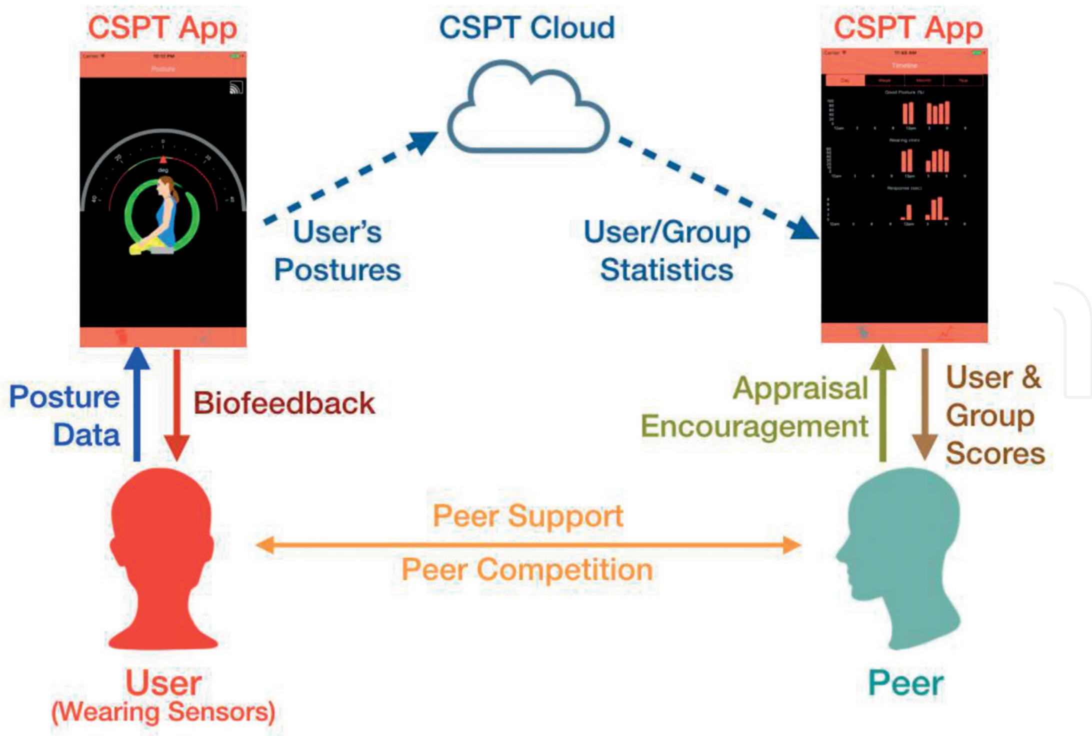

Figure 4. The CSPT framework.

4. CSPT system design

The CSPT system consists of three subsystems: wearable posture training headset, social-networked posture training App and cloud services subsystems. Each subsystem is described as follows:

4.1. Wearable posture training subsystem

The wearable posture training headset subsystem is a sophisticatedly designed, earhook headset that is equipped with a real-time sensory system to monitor head and neck posture. The sensory system is an embedded system with dedicated hardware of accelerometer functions to detect and transmit the three-axis acceleration values of the device continuously. We adopt a 32-bit ARM Cortex M0 microprocessor [48] as the core of the embedded system. The microprocessor operates at CPU frequencies of 30 MHz and equips with 16kB of flash memory and 4kB of SRAM with AES 128-bit encryption.

A three-axis accelerometer is used in the embedded system to detect the attitude of the posture monitoring hardware, that is, its pitch, roll and yaw. The accelerometer is featured by its ultra-low power, high performance, micro-electro mechanical system (MEMS) motion sensor for lightweight and long-lasting applications and wearable devices. The accelerometer is used to measure the accelerations of three axes of pitch, roll and yaw and generate 16-bit data streams with output rates in hundreds Hertz. The analog readings measured by the accelerometer are first digitalized and then sent to the 32-bit microprocessor through serial communication interfaces of I2C (Inter-Integrated Circuit) or SPI (Serial Peripheral Interface). The received signals are then filtered and calculated to generate the tilt angles of the posture monitoring hardware with Eq. (1).

4.2. Social-networked posture training CSPT App subsystem

The social-networked posture training CSPT App subsystem is the main interface to posture training users and their peers. The CSPT App provides a number of functions including gateway of sensor data, posture data processing, fuzzy logics and posture determination, biofeedback initiating, data feeder to the cloud and presentation or rendering the historical and analytic posture information. The CSPT App is also a social networking graphical user interface (GUI) for posture training and information sharing among individuals and their peers.

As the key element in the CSPT system, the CSPT App executes and manages many tasks, including signal processing, posture determination, biofeedback and data management to cloud computing. It receives, processes and further transmits posture angles. It determines the good posture and decides to notify when biofeedback is needed. The CSPT App renders the analytic data streams from the cloud, manages identity and access control and does encryption/decryption of the data and user ID, as the platform for chatting, messaging and file sharing of social network functions.

The CSPT App is also a notifier for people to receive alerts or warnings so that they can correct the poor posture immediately. When a biofeedback is enabled, the CSPT App plays default or customized sound or music and makes the smartphone vibrate for a short period of time to notify the users to change their bad posture. The smart feature of the CSPT App enables the intelligent detection of wearable devices so that no sound, music or vibration is made when the wearable devices are not attached or out of their operating space like being left on the desk. To avoid annoying, the notification period increases when the bad posture continues.

The friendly GUI of the CSPT App is the core to people. The CSPT App renders the analytic data streams from the CSPT Cloud. People can watch and be aware of the real-time status of their postures and realize how good or poor their head/neck and low back postures are. People can also glance over their peers' posture training performance. Based on the historical data from the cloud, people can explore their analytics, including the percentages of maintaining good postures, total wearing times and average response times. The resolution of time scales spreads from day, week, month, to year. **Figure 5** depicts two screenshots of the CSPT App GUIs for the analytic report in the day (right) and for poor posture (left), respectively.

The light speed advance of mobile technologies always makes the smartphone markets and products dazzling. Backward compatibility is a non-negligible issue in developing smartphone apps, especially to the Android platform. Not every smartphone is fresh new and up-to-date. For young kids and teens, some of them may use cheap-but-obsolete styles or their parents' used smartphones. These legacy smartphones usually use old operating system (OS) and supporting interfaces that are even unable to upgrade. In order to maximize the compatibility to most existing smartphones, the development of the CSPT App subsystem has to consider various and many smartphone models from different manufacturers with different OS and software versions. As compared to the development of other subsystems, it is so tedious and challenging.

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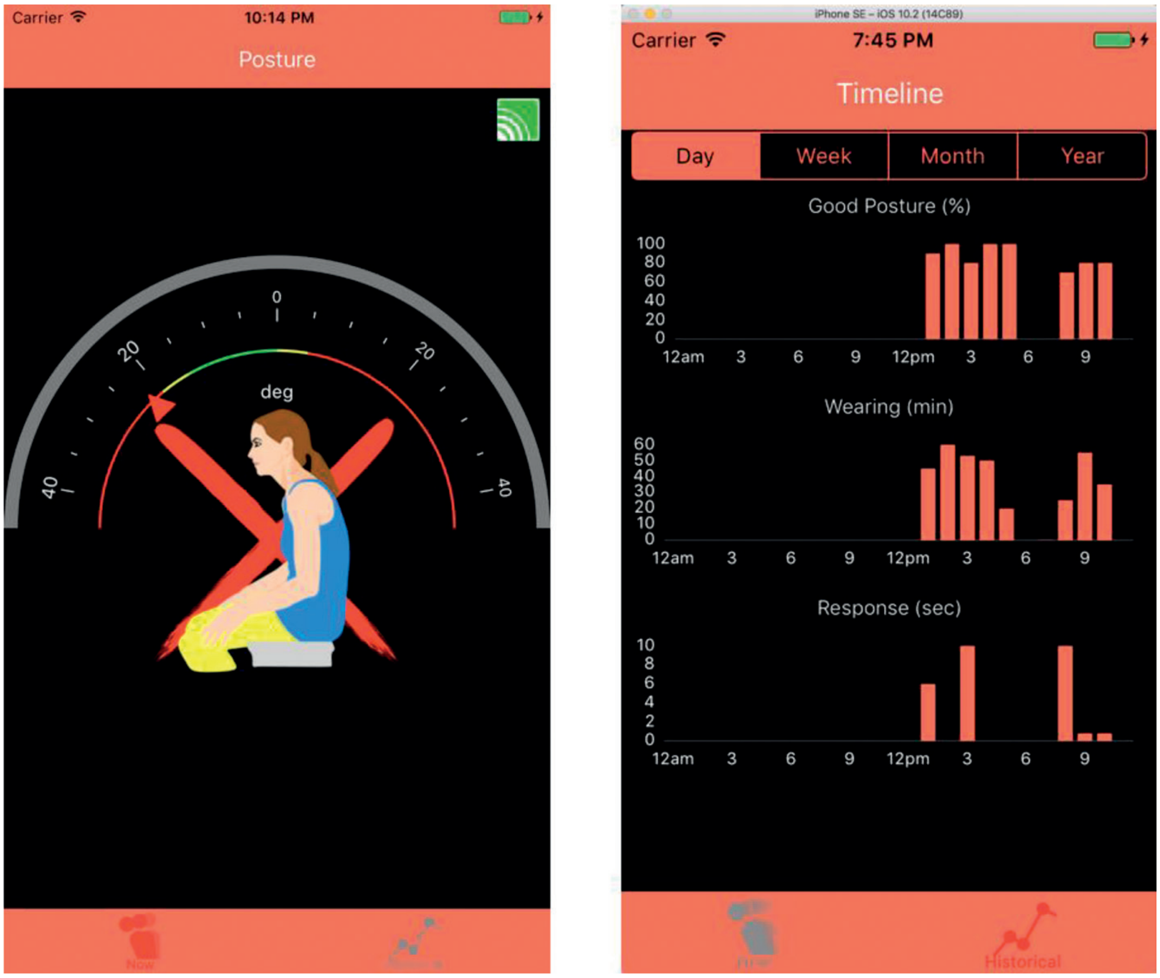

Figure 5. Screenshots of CSPT App (left: poor posture, right: analytics).

4.3. CSPT Cloud Services subsystem

The CSPT Cloud Services subsystem manages user data, generates the analytics and provides social network services for posture training. Web services with the on-demand computing platform operating from 12 geographical regions across the world are adopted to provide the CSPT cloud services. NoSQL databases are built to manage user data, posture angles and analytics.

5. Experiment design

To validate the effectiveness of the proposed CSPT posture training framework, we design several experiments considering a group of six teens in a middle school in San Jose, California, USA, whose families are similar in their race of Asian Americans, socioeconomic status, occupational status, family size, housing, geographic location, ethics and morals. The six teens denoted as “C,” “E,” “GC,” “GW,” “H” and “L,” by the first letter(s) of their names, respectively, are all 8th graders in the school and friends to each other. They study, play and chat in very close proximity to each other of the group.

5.1. Experiment method

Our design of experiments has four objectives as follows:

- to validate the effectiveness of the developed posture monitoring wearables;
- to validate the effectiveness of the proposed CSPT posture training framework;
- to study the effects of peer influences on posture training; and
- to study the effects of biofeedback on posture training.

The following three scenarios are designed for the experiments as follows:

Scenario S1: Both the biofeedback and social network functions are DISABLED.

Scenario S2: Biofeedback is ENABLED but social network function is DISABLED.

Scenario S3: Both the biofeedback and social network functions are ENABLED.

We conducted the experiments in each student's home with the guidance of students' parents. Each student was equipped with a wearable training headset, a training lumbar belt and the posture training CSPT App. They were asked to wear the training headset and lumbar belt for at least 60 min a day. The experiments were carried out from October 17th to 21st and from October 24th to 28th, 2016, detailed as follows:

Scenario S1 was conducted first on October 17th and 18th. Scenario S2 was followed and conducted on October 19th, 20th and 21st. Scenarios S3 was conducted from October 24th to 28th. Before each experiment, all the teens do not know about any details of the three scenarios. For the first 2 days (October 17th and 18th), each teen was asked to wear the headset and belt without knowing anything about biofeedback and social network functions. They were told and became aware of the biofeedback music, voice and vibration in Day 3 (October 19th). On October 24th, the teens were asked to download App's social network function where they can glance at their friends' training scores. During the experiments, all the teens knew who of their peers are participating in the experiments. Teens can share their observations and knowledge to each other during the entire experiment period.

5.2. Experiment data collection

The experiment data of time-series posture data are generated by the wearable devices, collected by the CSPT App and sent to the CSPT Cloud. The experiment data are transferred through a RESTful [49] protocol-based application programming interface (API) to the Cloud. We utilize Node.js [50], featured by its fast, scalable and easy implementation for API, mobile, web and Internet of Things (IoT), in implementing the mobile API to access the data and services.

6. Experiment results

The effectiveness of the posture training tool and the proposed CSPT framework is deliberately reviewed and validated throughout the experiments. **Table 1** shows the experiment

Date	Good posture (%)						Wearing time (min)						Scenario
	C	E	GC	GW	H	L	C	E	GC	GW	H	L	
Oct. 17	65	85	80	78	74	87	60	61	60	63	61	74	S1
Oct. 18	68	88	82	76	77	85	61	64	60	62	61	77	
Oct. 19	89	95	96	95	90	98	60	72	62	62	62	75	S2
Oct. 20	90	92	95	92	95	99	61	68	68	61	64	82	
Oct. 21	85	95	90	93	92	98	61	69	65	60	61	86	
Oct. 24	92	100	98	100	98	100	62	113	85	96	89	127	S3
Oct. 25	95	100	99	100	99	100	87	151	90	111	120	149	
Oct. 26	94	100	100	99	100	100	102	155	121	160	158	156	
Oct. 27	99	100	100	100	100	100	115	169	162	176	159	180	
Oct. 28	99	100	99	100	100	100	152	192	170	179	167	190	

Table 1. Experimental results.

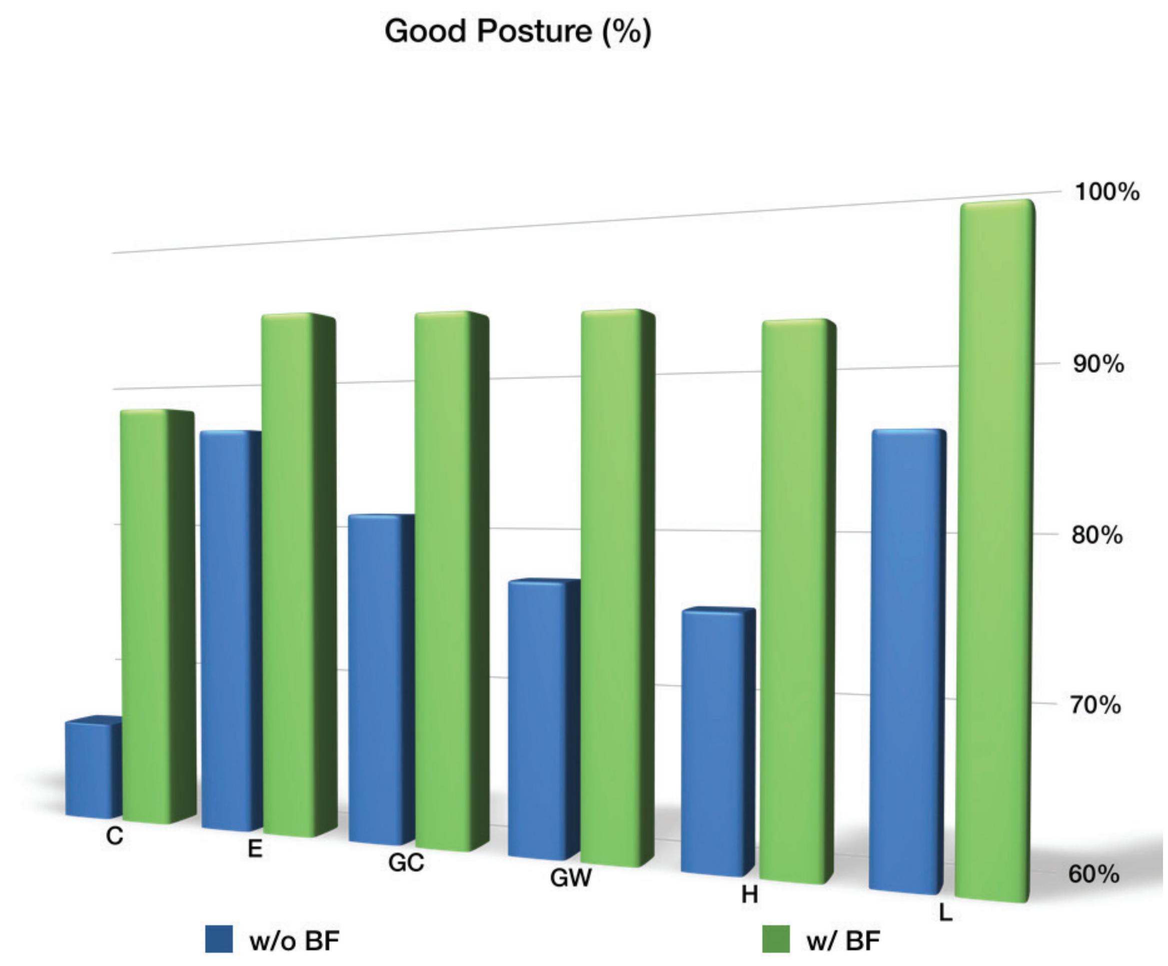

Figure 6. Comparison of results without and with biofeedback.

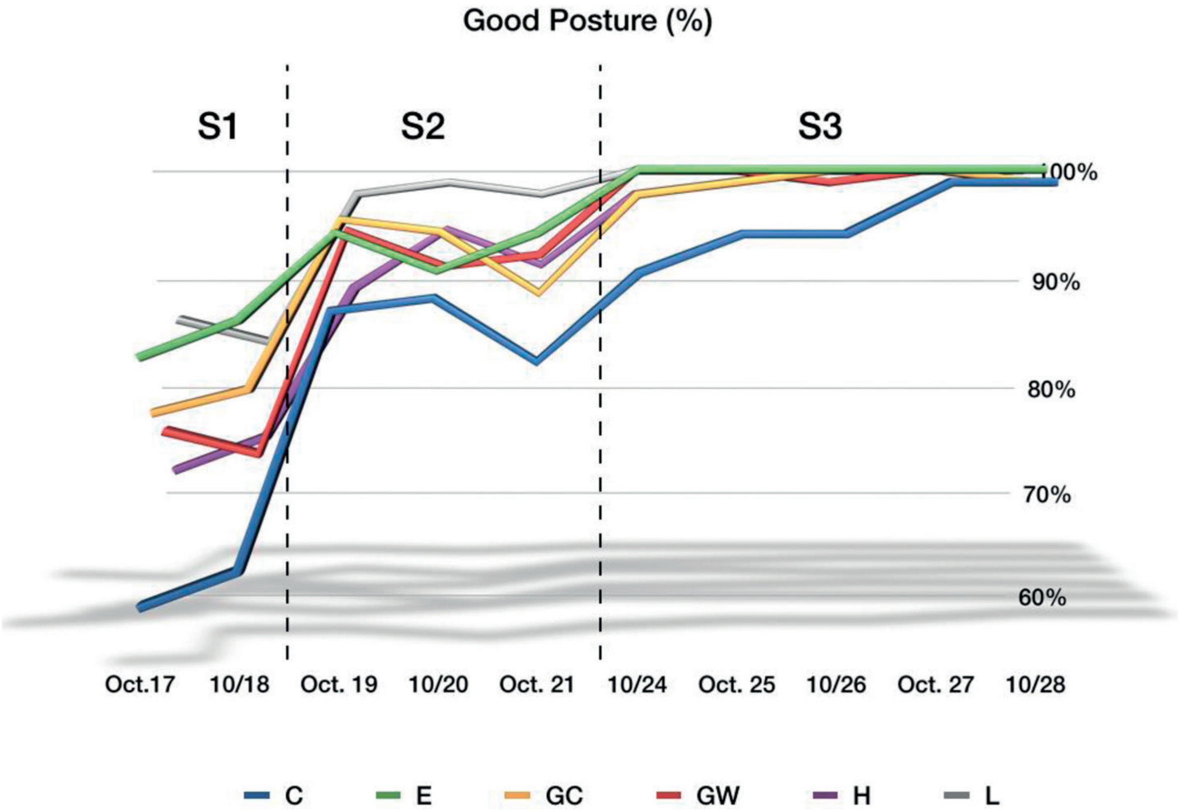

Figure 7. Results of good posture percentages of time (%).

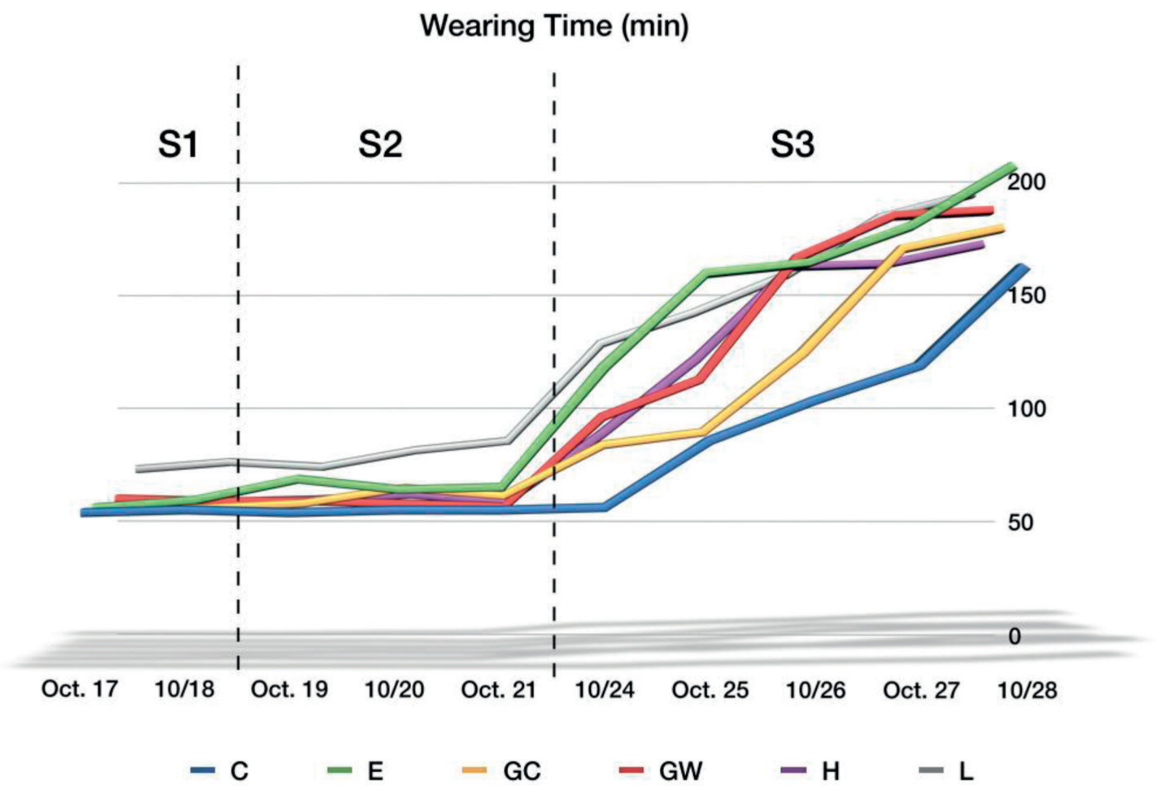

Figure 8. Results of wearing time (minutes).

results of percentages of good posture (%) and the total wearing times (min) of the six students. Comparison of average good posture percentages between Scenarios S1 (without biofeedback) and S2 (with biofeedback) is depicted in **Figure 6**. Note that biofeedback does facilitate the increase of percentages of good posture for all the teens significantly. Similar results on the effectiveness of biofeedback on forward head posture improvements have been observed and reported in the literature [11, 45].

Figure 7 demonstrates the results of percentage (%) of time in good posture of each teen in Scenarios S1, S2 and S3. Obviously, teens are encouraged by peer influences from their social network and social support in maintaining good posture. Results of wearing times of each teen in Scenarios S1, S2 and S3, as depicted in **Figure 8**, comply with the same observations. As compared to teens' wearing times in Scenarios S1 and S2, peer competition and encouragement do promote longer wearing times in Scenario S3, respectively. The proposed collaborative, social-networked approach is effective for teens of peer influences to be supported, encouraged and collaborative to achieve the goals of maintaining good posture.

7. Conclusion

This chapter develops a posture training tool to invoke people' awareness of their bad posture so that they can timely improve their poor posture and maintain good posture while sitting. A collaborative, social-networked posture training (CSPT) approach is used in the design of the posture training tool. Three technologies of real-time posture monitoring, biofeedback and collaborative social networks are adopted in the CSPT framework, which is composed of a sophisticated posture monitoring headset, a training lumbar belt, a smartphone, a social-network CSPT App and cloud services. Experiments are conducted to validate the effectiveness of the proposed CSPT framework with a group of six middle-school teenagers. We design three testing scenarios to explore the effects of biofeedback and social networking. Our experiment results indicate that the proposed CSPT framework with posture monitoring and biofeedbacks are effective in increasing the percentage of time in good posture for each teen in the group. Experiment results also show that peer influences and social support are crucial and effective to encourage the teens in maintaining good posture and being willing to wearing the posture training tool for longer time.

Some mHealth apps like iOS Health [51] and Google Fit [52] and other mobile wearable fitness devices [53] are available in the market. To our best knowledge, none of them implement social networks or social media functions. Future research may develop an integrated social networks platform to provide health services or bio-sensing functions of heartbeats, blood glucose and electrocardiogram (EKG). Although the motivation of this research is preliminarily for posture training while sitting, the applications of the proposed CSPT framework and the devices are not limited to sitting posture only. They can be applied to other workplace environments, sports and performance psychology. Further research directions may also extend the developed biofeedback techniques to applications like driver sleepiness detection, core stability training, therapeutic, fitness and so on.

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