Smart Pose: Mobile Posture-aware System for Lowering Physical Health Risk of Smartphone Users

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Abstract
With the widespread use of smartphones, users tend to use their smartphones for a long period of time with unhealthy postures, bending forward their upper body including the neck. If users keep such an unhealthy posture for a long time, their neck and back muscles get chronically strained, which might cause diseases such as cervical myalgia. To prevent these diseases, we propose a new methodology to monitor the posture of smartphone users with built-in sensors. The proposed mechanism estimates a value representing user postures like head/neck tilt angle by analyzing sensor data from a front-faced camera, 3-axis accelerometer, and orientation sensor. It then informs the user if the estimated value is maintained within the abnormal range over a pre-defined time.

Author Keywords
Posture monitoring; smartphone sensors; neck tilt angle; musculoskeletal disorders; cervical myalgia

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User interfaces – ergonomics, user-centered design

General Terms

Design; Human Factors; Measurement

Introduction

An increasing number of users are enjoying a variety of media contents and applications in their everyday life thanks to the smartphone. However, many users may use their smartphones with their head lowered and the device close to their waist or lap while traveling, for example, on the bus or subway. Due to the result of using mobile devices in such a posture for a long period of time, the user's muscles around her/his neck can be strained. More specifically, continuing an incorrect posture in using a smartphone can cause various musculoskeletal disorders like neck muscle pain and forward head posture syndrome.

According to the recent report of James Rind, a musculoskeletal physiotherapist in UK, repetitive and regular usage of the smartphone can lead to cumulative damage and musculoskeletal disorders to the user [4]. He warned that the commonly adopted static posture of the neck, shoulders, and upper spine may lead to physical problems later in life. To prevent such health risks, users need to keep the smartphone at eye level, change their posture regularly, and reduce the time of smartphone use. However, users may not recognize such risks, and even when some users do recognize the risks, many of them may not pay enough attention to maintain a correct posture while they are immersed in using the smartphone.

To tackle this problem, we propose a new mobile posture monitoring system based on the analysis of physical behavior of smartphone users. To understand a user's posture, the proposed system checks whether the user is facing the screen with the smartphone in hand by analyzing captured facial images of the user and 3-axis accelerometer data of the device. Then, the system periodically estimates the tilt angle of the user's neck by measuring the cumulative average of tilt angles of the device only when the user is watching the screen while holding the device in her/his hand. This is based on the findings that the tilt angle between the user's neck and the device is positively correlated when the user is using the smartphone because the user naturally tends to keep the viewing angle optimal to clearly see characters or images on the screen with comfort. The tilt angle of the device is measured by an orientation sensor which computes the device's orientation in 3 dimensions. According to the proposed system, if the estimated tilt angle of the user's neck exceeds a permissible range for a specific time period, we can inform the user about her/his poor posture by various means such as vibration, text message, or sound alarm.

Related Work

Many researchers have suggested various methods and systems to monitor the postures of people. Arteaga, S. *et al*. reported an accelerometer-based posture monitoring system for stroke survivors [2]. They developed a monitoring hardware composed of a 3-axis accelerometer, beeper, LED light, and vibrator, then placed 10 monitoring devices above body parts like the knee, shoulder, and wrist of participants. When a bad posture is detected redundantly, the proposed system gives warning to the user and stores inappropriate posture data as a log. Farra, N. *et al*. developed a system to monitor spine health by measuring the inclination of the user's upper back and stress exerted on the spine [5, 6]. To achieve this, they attached special sensors such as an inclinometer and load cells at the neck and shoes of the user, respectively. All of the abovementioned approaches are novel and well-designed for their own purpose. However, users should be equipped with additional sensors on their body and this restriction prevents its widespread and ubiquitous use.

Additionally, Hong, D. *et al*. also implemented a hardware component named *SEPTIMU* embedded inside conventional earphones to monitor the user's postures [7]. By combining the output of a 3-axis accelerometer and gyroscope on the *SEPTIMU*, they determined how long the user stays in the same posture without moving. This system only checks whether users shift their posture by analyzing gathered sensor data. Schrempf, A. *et al*. developed a framework for the classification of sitting postures [10]. They integrated four force transducers into the traditional chair and calculated a posture cost function based on a biomechanical model. By using the posture cost function, they were able to identify postures which can lead to lower back pain of the user. This approach is well-suited for indoor situations like offices, but cannot be applied to the case of mobile phone usage.

Alternatively, Baek, J. *et al*. proposed a method for monitoring the postures of a user during operation of a mobile phone in three activities such as sitting, standing, and walking [3]. To classify postures of the user into one of the three categories, they calculated the tilt angle between the device and the Earth's surface from values of a 2-axis accelerometer attached to the device. That is, they measured the tilt angle of the user's device for activity recognition and context-awareness rather than posture monitoring for health benefits, because they were not concerned about detailed conditions of body parts of the user.

Mobile Posture-aware System

Figure 1 shows the conceptual diagram of the posture monitoring system described in our previous work [9]. When a user starts to use a smartphone, the system checks whether the user is operating the device in her/his hand. To determine whether the user is operating the device, it periodically checks the face of the user from captured images by the front camera on the smartphone using the face detection library in Android APIs and counts how many times the device is trembled by the user's hand during a single notification cycle by examining whether the x, y, or z value of the accelerometer exceeded the predefined threshold. If a user's face is detected and the device has been shaken several times, the user is probably watching the screen with the device in hand. We defined this kind of physical activity as the operation posture.

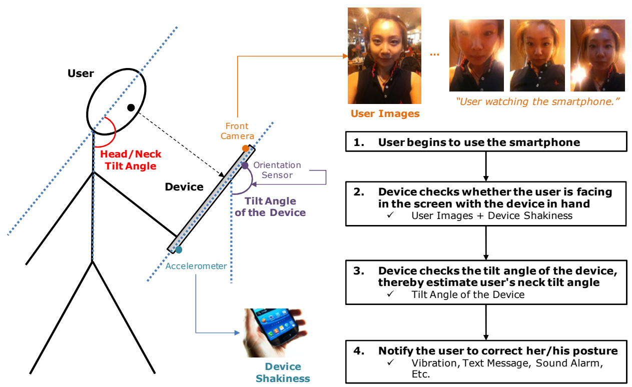


Figure 1. Conceptual diagram of mobile posture-aware system.

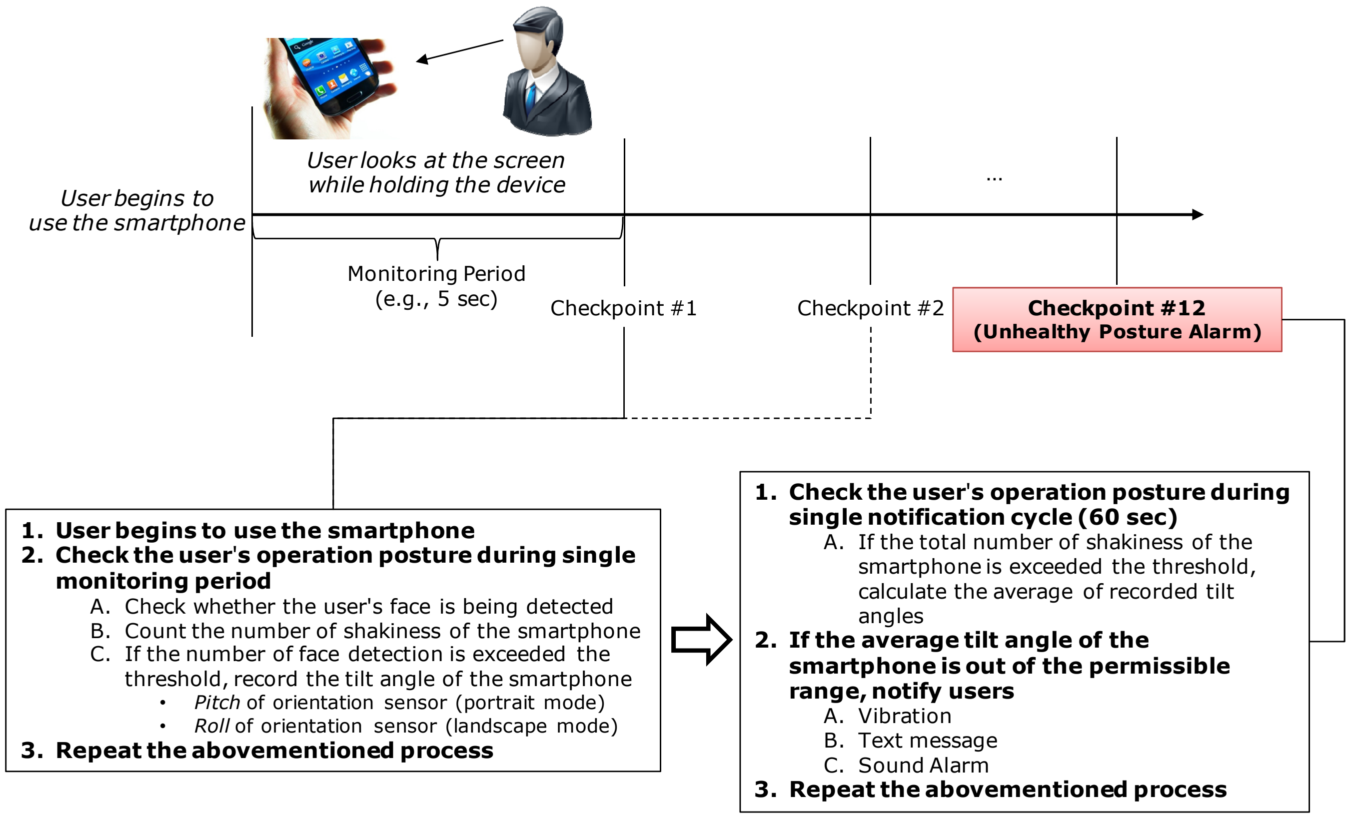


Figure 2. Workflow of the proposed system.

Basic Idea

If a user is in the operation posture, the tilt angle of the user's neck and the device may be correlated, because the user wants to maintain the appropriate viewing angle between the display and eyes, to be in a range giving acceptable visual quality. Therefore, we can estimate the user's neck tilt angle by examining the tilt angle of the device relative to the vertical axis using rotation angles computed by the orientation sensor. Internally, the orientation sensor calculates the inclination of the device by applying measurements from the 3-axis accelerometer and magnetic sensor to a rotation matrix. The abovementioned process is depicted in Figure 2 and the algorithm for estimating the neck tilt angle is described as follows.

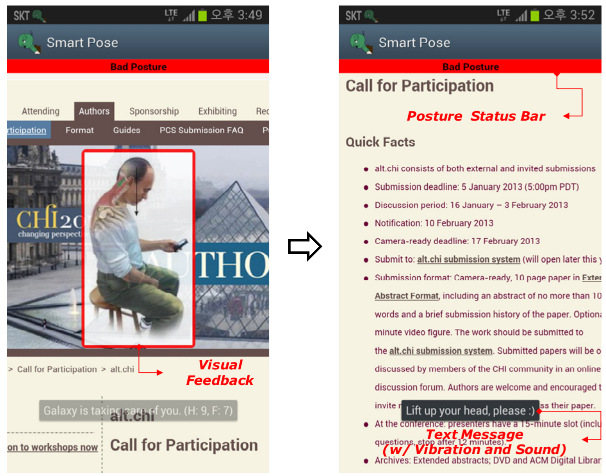
Algorithm
When a user is watching the screen while grasping the device vertically or horizontally, the cumulative average tilt angle (*CATA*) of the device is computed as follows:

$$CATA = \frac{\sum_{i=1}^{n} |TiltAngle_i + 90|}{n}$$

where *TiltAngle* is the current *pitch* or *roll* value (e.g., -87.3) of the orientation sensor in the device, and *n* is a number of the operation posture detected, respectively. We will discuss the abnormal range of *CATA* in a later section.

Implementation
As a proof of concept, we developed an Android application named *Smart Pose* for Samsung Galaxy S III which has various built-in sensors including front camera, accelerometer, and orientation sensor. According to the workflow depicted in Figure 2, we implemented a *Smart Pose* for the Android 4.1.1 platform (i.e., Jelly Bean), and used official Android APIs for detecting the user's face and calculating shakiness and tilt angle of the device. For natural user experience scenarios, we embedded the proposed system into the traditional web browsing application using an open source web browser engine named *WebKit*.

The reason why we implemented *Smart Pose* as an application rather than a service is to follow privacy and security policies of the Android operating system. Google prohibits using a camera function as the background service to prevent misapplication of it, for example, spy camera. However, in case of deploying *Smart Pose* on the commercialized product, the proposed system can be implemented as a service by modifying Android operation system just like *Smart Stay* in Samsung Galaxy S III. Screenshots of the *Smart Pose* is depicted as Figure 3.



a) Incorrect posture detected b) Alarm

Figure 3. Demo application - Smart Pose.

Validation
To verify the validity of our approach, we investigated the unusual range of *CATA* using existing posture analysis equipment named *BackMapper* [1]. *BackMapper* can measure the position, balance, or inclination of various parts of a human body, and visualize measurement results as 3D images. Also, it performs a diagnosis of the measured value of each body part by comparing with the predefined normal

figure. Then, we recruited participants to analyze their various postures with the *BackMapper*. By using this result, we approximately determined the abnormal range of *CATA*, and applied it to *Smart Pose*. Finally, we asked participants to test *Smart Pose*. More detailed explanations including the experiment are as follows.

Experiment Setup

PARTICIPANTS

Twelve participants (10 males in their 30s, 2 females in their 20s) from our research institute were recruited for the experiment. All participants agreed to the usage of measured data related to their postures for our research, and received about $10 individually.

PROCEDURE

Each participant was required to maintain the following four postures while using a smartphone:

1. Stand with head lifted (Correct posture)
2. Stand with head bent (Incorrect posture)
3. Sit with head lifted (Correct posture)
4. Sit with head bent (Incorrect posture)

We regarded 1 and 3 as correct postures and 2 and 4 as incorrect postures because holding the head up and keeping the device at eye level is the most desirable posture for smartphone users according to orthopedists.

Participants maintained each posture for one minute while executing *Smart Pose* on their smartphones. During this period, *BackMapper* measured the structure of the participant's upper body and *Smart Pose* calculated *CATA*, respectively. For this experiment, all participants attached four visual markers to back of their neck, shoulder, and waist (*BackMapper*), and read a designated article related to a movie with a smartphone (*Smart Pose*).

Experiment Results

As mentioned earlier, *BackMapper* provides a detailed report per measurement to inform the current condition of each body part based on orthopedic knowledge. According to the report of *BackMapper*, the participants' backs were bent especially when they were watching a smartphone while both standing and sitting with their head bent. That is, their necks were also bent accordingly to see the screen of the smartphone in the posture 2 and 4. More specifically, the thoracic angle represents inclination of body parts between the neck and waist; therefore, it may also represent the tilt angle of the neck while people are watching their smartphone.

Results / Postures	BackMapper		Smart Pose	Correlation Coefficient
	Ratio of high risk reported	Avg. thoracic angle (STDV)	Avg. CATA (STDV)	(between thoracic angles and CATAs)
1. Stand w/ head lifted	0% (0/12)	8.33° (1.97°)	15.02° (9.24°)	0.4714
2. Stand w/ head bent	75% (9/12)	15° (3.46°)	64.76° (10.21°)	0.8433
3. Sit w/ head lifted	16.7% (2/12)	10.83° (3.34°)	14.67° (8.99°)	0.0309
4. Sit w/ head bent	83.3% (10/12)	17.58° (4.27°)	66.69° (9.01°)	0.6891

Table 1. Result of posture analysis for 12 participants.

We summarized the result of posture analysis in Table 1. When participants took incorrect postures (i.e., posture 2 and 4), the average thoracic angle was 15° (*STDV*=3.46°) and 17.58° (*STDV*=4.27°), respectively, and *BackMapper* warned us of these values in most cases. Correspondingly, *Smart Pose* computed *CATA* as 64.76° (*STDV*=10.21°) and 66.69° (*STDV*=9.01°), respectively. Correlation coefficient (r) between the thoracic angles and *CATAs* was 0.8433 for the incorrect posture 1 (stand w/ head bent), 0.6891 for the incorrect posture 2 (sit w/ head bent), 0.4714 for the correct posture 1 (stand w/ head lifted), and 0.0309 for the correct posture 2 (sit w/ head lifted). This statistical analysis shows that when the participants take incorrect postures, correlation between the thoracic angles and *CATAs* is much stronger compared to correct postures. This means that we can use the *CATA* as a meaningful metric to estimate the thoracic angle for incorrect postures at least.

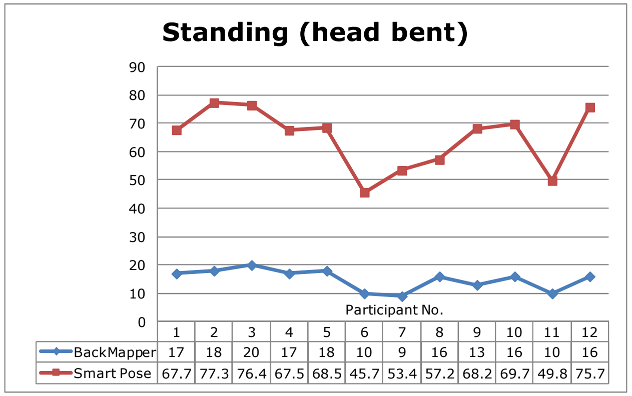


Figure 4. Dataset for the incorrect posture 1.

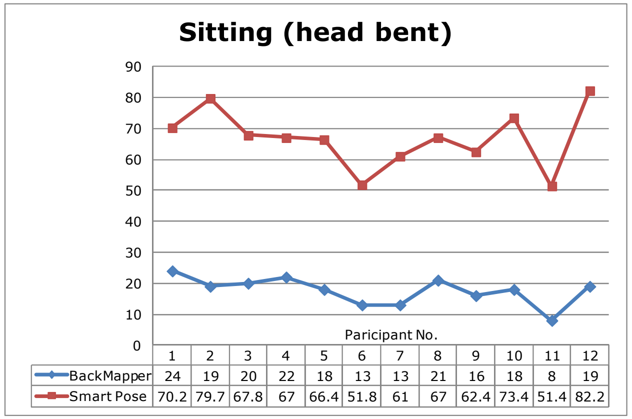


Figure 5. Dataset for the incorrect posture 2.

We presented gathered dataset for incorrect postures in Figure 4 and 5, and presented the result of a regression analysis on them in Figure 6 and 7.

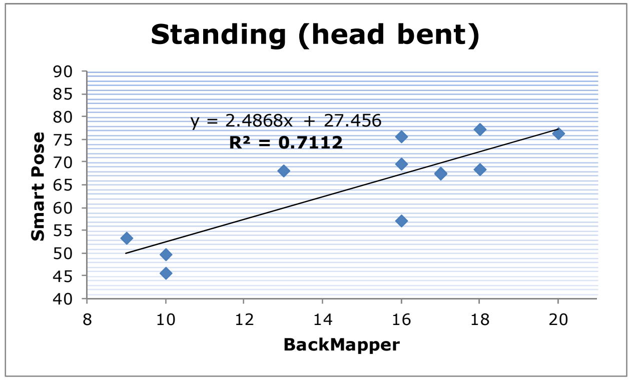


Figure 6. Regression analysis on dataset for the incorrect posture 1.

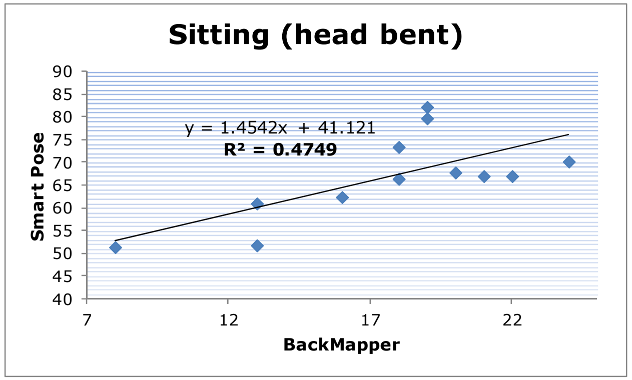


Figure 7. Regression analysis on dataset for the incorrect posture 2.

Also, the ratio of thoracic angle to *CATA* was approximately 1:4.3 and 1:3.8 for these two incorrect postures. We didn't expect the 1:1 correlation between the thoracic angle and *CATA* because *BackMapper* can only measure the inclination of the upper body including the head rather than angle between the cervical and thoracic vertebrae of the people. The standard deviation of *CATA* is naturally higher than thoracic angle because *BackMapper* was fixed on the ground, while the smartphone was handled with hands, thereby causing more variance on the measured data. However, the standard deviation of *CATA* is much smaller than the mean difference between results of correct and incorrect postures. An important finding is that we can estimate the thoracic angle (i.e., *BackMapper* result) from *CATA* by using the abovementioned correlation, thereby can warn users of their incorrect postures. As a result, we roughly determined an impermissible range of *CATA* as from 56.12° to 75.34° for both standing and sitting postures. For example, if the *CATA* is 65, then we can estimate the thoracic angle as 16.25 and assume that the user is probably bending the head.

User Study

We applied the abovementioned range of *CATA* to the *Smart Pose*, and tested it under real world situation for 12 participants. As a user scenario, we chose a web browsing because it is one of the most common activities of smartphone users in their everyday lives. When a participant maintains an abnormal range of *CATA* for a single notification cycle (i.e., 1 min) in watching the screen, *Smart Pose* informs the participant through vibration, text message (i.e., "Lift up your head, please."), and sound alarm simultaneously to recommend she/he change her/his current posture.

After tests were performed, we asked participants questions on their opinion about self-awareness of incorrect postures in their everyday smartphone usage (1), approximate time of smartphone use with such an incorrect posture (2), recent experience of muscle pain around their necks (3), accuracy of the proposed posture monitoring method (4), and general satisfaction and applicability of the demo application for their daily lives (5). We used 5 point scale in answering question 1, 3, and 5. Results of this survey are described as follows.

1. Have you ever cared about your posture while using smartphone? → 2.8 (Strong No:1 … Strong Yes:5, *STDV*=1.28)

2. Approximately, how long do you use the smartphone with incorrect postures every day? → 49.2 (Minutes, *STDV*=22.25)
3. Have you ever experienced muscle pain around your neck in the past year? → 3.4 (Strong No:1 … Strong Yes:5, *STDV*=1.1)
4. Did *Smart Pose* properly inform you when you take an incorrect posture? → Yes (11/12, Hit ratio: 91.67%)
5. Do you have intent to change your posture when *Smart Pose* informs you of your incorrect postures? → 4.6 (Strong No:1 … Strong Yes:5, *STDV*=0.49)

In addition, most of the participants considered a text message as the most suitable notification method, because it arouses relatively less interruption than other methods in their smartphone usage. Figure 8 shows this finding.

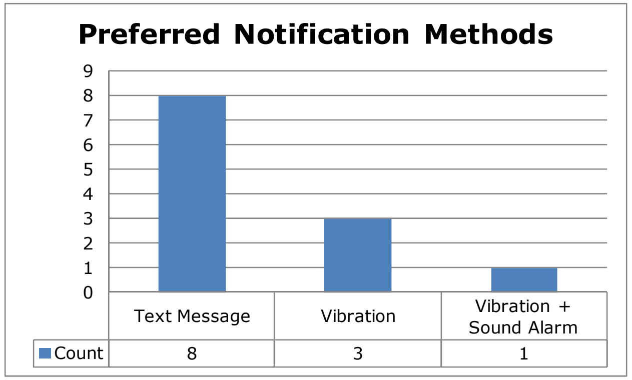


Figure 8. User study - preferred notification methods.

Discussion

The results of the experiment and user study show that our system can reasonably detect smartphone users' incorrect postures and inform them. We present some limitations to be considered to make our approach more practical.

Limitations

We have to check the degree of inclination of the participant's head or neck more accurately. Even though the thoracic angle computed by *BackMapper* represents this measure, especially when users watch the smartphone, they are still able to move their head exceptionally. In other words, we should measure the exact angle between the cervical and thoracic vertebrae of the participant using special equipment such as [8]. This will help determine more precise impermissible range of *CATA*. Also, we have to define an acceptable time of smartphone usage with incorrect postures to inform users in a timely manner. To achieve this, we should record the point of time when users feel discomfort or pain in their muscle. To the best of our knowledge, however, there are no ways to measure this figure medically. Therefore, we need to conduct a clinical study to find this value via paper-based questionnaires intended for unspecified individuals. To that end, we will collaborate with medical professionals.

Conclusion

In this paper, we propose a new methodology for identifying incorrect postures of smartphone users using built-in sensors only. Through the comparative analysis between degrees of inclination of participants' upper body including neck and average tilt angle of the smartphone in use, we determined an abnormal range of the tilt angle of the device as from 56.12° to 75.34°.

By using the proposed system, most of the participants were able to become aware of their incorrect postures, which are usually unnoticed, and they disclosed their intention to change their postures when informed by the proposed system. As noted earlier, there is some work to be done before our proposed system can be used clinically. However, we believe that it certainly arouses smartphone users' attention to consider their posture while using the device; thereby providing less strain on their body.

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References

[1] ABW GmbH BackMapper, Detecting Human Surface and Structure. http://backmapper.abw-3d.de/.

[2] Arteaga, S., Chevalier, J., Coile, A., Hill, A.W., Sali, S., Sudhakhrisnan, S. and Kurniawan, S. Low-Cost Accelerometry-Based Posture Monitoring System for Stroke Survivors. In *Proc. ASSETS 2012*, ACM Press (2012), 243-244.

[3] Baek, J. and Yun, B. Posture Monitoring System for Context Awareness in Mobile Computing. *IEEE Transaction on Instrumentation and Measurement 59*, 6 (2010), 1589-1599.

[4] The Chartered Society of Physiotherapy, Physio warns of smart phone RSI risk. http://www.csp.org.uk/frontline/article/physio-warns-smart-phone-rsi-risk/.

[5] El-Sayed, B., Farra, N., Moacdieh, N., Hajj, H., Haidar, R. and Hajj, Z. A Novel Mobile Wireless Sensing System for Realtime Monitoring of Posture and Spine Stress. In *Proc. MECBME 2011*, IEEE (2011), 428-431.

[6] Farra, N., El-Sayed, B., Moacdieh, N., Hajj, H., Hajj, Z. and Haidar, R. A Mobile Sensing and Imaging System for Real-Time Monitoring of Spine Health. *Journal of Medical Imaging and Health Informatics 1*, 3 (2011), 238-245.

[7] Hong, D., Zhang, B., Li, Q., Nirjon, S., Dickerson, R., Shen, G., Jiang, X. and Stankovic, J.A. Demo Abstract: SEPTIMU – Continuous In-situ Human Wellness Monitoring and Feedback using Sensors Embedded in Earphones. In *Proc. IPSN 2012*, ACM Press (2012), 159-160.

[8] JTech Dualer IQ Inclinometer, Range of Motion Evaluation of Joints. http://www.jtechmedical.com/solutions/commander/dualer-iq-digital-inclinometer/.

[9] Lee, H., Choi, Y.S. and Lee, S. Mobile Posture Monitoring System to Prevent Physical Health Risk of Smartphone Users. In *Proc. UbiComp 2012 Adjunct*, ACM Press (2012), 592-593.

[10] Schrempf, A., Schossleitner, G., Minarik, T., Haller, M. and Gross, S. PostureCare - Towards a novel system for posture monitoring and guidance. In *Proc. IFAC 2011*, Elsevier (2011), 593-598.