Office Workers Syndrome Monitoring Using Kinect

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***Abstract*—Many office workers today sit and work at computers for extended periods of time, which can result in a group of symptoms called "Office Workers Syndrome". To help prevent these symptoms, we propose a novel system to monitor computer users by using a Kinect camera. Firstly, data mining classification is applied for detection of prolonged sitting, while mathematics that include a spherical coordinate system and geometry as well as threshold models is applied to detect unhealthy postures. Secondly, the system gives an alert to the user when unhealthy postures are detected, via simple pop-up/voice messages or via an alerting device developed by using a microcontroller. Moreover, this research also focuses on enhancing the user experience, various user-interfaces and data visualization techniques for generating useful summary reports are provided.**

Keywords—Health and Medical Informatics; Ergonomics; Office Workers Syndrome; Kinect Camera; Human Gesture Recognition; Data Mining; Classification; Visualization.

I. INTRODUCTION

The purpose of this study is to extend our existing system [1]. The system is intended to help computer users prevent office workers syndrome [2-3] by monitoring their sitting habits. Although prolonged sitting and improper sitting postures are two major causes of the syndrome, only the detection of the prolonged sitting is done by the existing system. Therefore, in this study, unhealthy sitting posture detection functions are added. Algorithms for translating human body angles are based on a spherical coordinate system [4] and geometry [5].

The goal of this study is to develop a real-world practical sitting monitoring system while enhancing the user experience. We introduce various user-interfaces and data visualization techniques to help the user easily interpret the result, and make the system flexible enough to meet the different needs of users. Summary reports with a selectable range of details can be generated, and graphs and images are used instead of plain texts.

II. LITERATURE REVIEW

A. *Office Workers Syndrome*

"Office Workers Syndrome [2-3]" is a group of symptoms commonly found in office workers caused by unhealthy work habits. It has become a common affliction, since many people now spend long periods of time sitting while working. This syndrome results in musculoskeletal pain, headache, aching arms, wrists and fingers, eye strain, and even serious diseases.

1) Low-back pain

For a long time, low-back pain has ranked among the most common health problems in industrialized societies and is a common cause of activity limitation [6]. A 2011 study revealed that $96 million was spent each year in the US as the total direct cost of chronic low-back pain-related health care utilization [7]. It was found to be the most common medical disorder among the working-age population. The time spent using a computer shows a strong positive correlation with the likelihood of occurrence of low-back pain [8].

B. *Ergonomics*

1) Proper Sitting Posture

Ergonomics proper sitting posture [9] is defined as sitting upright with the head and neck vertically in-line with the torso, the body not bent down or back, and the body forward-facing.

2) Dynamic Sitting and Micro-Breaks

"Dynamic sitting [10]" and "micro-break [9]" are practices recommended by experts to reduce the risk of disease arising from sitting. These practices encourage the worker to perform body movements and take micro-breaks frequently during work. This is done to ensure a healthy level of musculoskeletal system activity, and to prevent ergonomic injury.

3) RULA and REBA principles

Rapid Upper Limb Assessment (RULA) [11] and Rapid Entire Body Assessment (REBA) [12] are methods for measuring the health risk levels of work-related disorders. They provide a quick and systematic assessment of the postural risks to a worker by analyzing the body angle and calculating the risk score for a specific moment. Both are used in this study for specifying threshold values of body angles for posture detection as well as the threshold for indicating health risk levels.

C. *Existing Sitting Monitoring Systems*

In 2007, Demmans et al. [13] developed a posture monitoring system which measured the angle between the neck and shoulder using FLX-01 Flex Sensors. Problems stated in this research were that the system was not useful in motivating users and also a low level of accuracy.

Mattmann et al. [14] proposed a prototype garment which 21 strain sensors had attached to it that recognized at least 27 upper body postures. The system had a limitation in differentiating similar postures, and it required more sensors to solve this problem.

Mutlu et al. [15] presented a practical approach towards sensing and recognizing seated postures. They avoided the use of expensive hardware and complex prediction algorithms. Nineteen pressure sensors were installed on a chair, and the cost of the sensors was about $100. The system had a limitation in upper body tracking.

In 2010, Zheng and Morrell [16] developed an ergonomic chair using 7 force-sensitive resistors; the chair would vibrate when an unhealthy sitting posture was detected. They claimed that office workers normally found visual feedback distracting. So their research aimed to correct chronic problems with as little disruption of the primary tasks as possible by using haptic feedback.

In 2013, Lee et al. developed the system called "Smart Pose" [17]. Smart Pose is a mobile posture-awareness system which uses only mobile built-in sensors which can estimate the user's postures such as head and neck tilt angle by analyzing sensor data from a front-facing camera.

III. Proposed System

Kinect is used as an input device by setting it up at an office worker's work station. The proposed system obtains input gesture data from Kinect's real-time skeleton data stream. Prolonged sitting detection is done by using data mining classification, while posture detection is done by the threshold model. The proposed system will alert the user when an unhealthy habit is detected, and it can also provide summary reports on the healthfulness of the user's sitting behavior.

1) *Prolonged Sitting Detection*

Data mining classification [18] is performed on the real-time skeleton data to detect prolonged sitting. D-Tree J48 [19] is the algorithm used for model building. The proposed system autonomously feeds 10 seconds of skeleton data into the model, and then the model classifies the class label if the user has a period of prolonged sitting or has a period of movement. The optimal model has achieved a 98% accuracy rate [1].

2) *Issues of Concern*

Robustness: The algorithms used for prolonged sitting detection and posture detection are reliable in various environments.

Data Recovery: During sitting monitoring, the system backs up data at fixed intervals of time.

Customization: The user can configure the system according to his or her preferences, e.g., change the interface for receiving system feedback and turn the alarm sound on/off.

Privacy: This application is intended for users who want a tool for monitoring and correcting their postures.

IV. Posture Detection

For posture detection, mathematics is applied for body angle translation, and threshold values are defined to detect human postures.

A. *Skeleton Data*

The Kinect camera obtains depth data from its sensors, and then calculates the position of body joints; each joint consists of position of 3D coordinates (*X, Y, Z*).

B. *Mathematics for Angle Translation*

In this research, the mathematics used to support angle translation are a spherical coordinate system [4] and geometry [5].

It can be concluded that when the axes in three-dimensional space are any combination of $\{X, Y, Z\}$; a position of 2 body joints (2 points) will create a right triangle of which the hypotenuse is a Euclidian distance from *Point 1* to *Point 2*, one leg is any axis in a Kinect coordinate (α: fixed direction), and the other adjacent leg is calculated by Pythagorean theorem by using the two remaining axes. When θ and φ are angles of corners that are not right angles, and when α is an opposite side of angle θ, the value of θ and φ (in degrees) can be calculated as in (1), (2) and (3). These can be summarized as shown in Fig. 1.

$$r = \sqrt{X^2 + Y^2 + Z^2} \tag{1}$$

$$\varphi° = acos\left(\frac{\alpha}{r}\right) * 180/\pi \tag{2}$$

$$\theta° = 90° - \varphi° \tag{3}$$

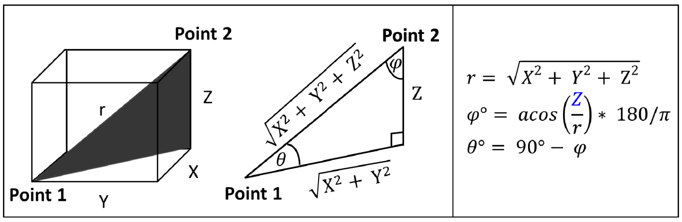

Fig. 1. Right Triangles Created by 2 Points (when $\alpha = Z$).

C. *Body Angle Translations & Threshold Models*

For posture detection, we applied the threshold model to detect postural changes when the user pitches the head, twists the body, stands up, or walks away for a break. The threshold values to indicate the angles for head pitch and twisted posture are from RULA and REBA as mentioned in Section II.B.3.

When the system starts, the user has to register in the system a "Base Posture", a healthy posture, which is then used to calculate the relative changes in the user's postures.

1) *Head Pitch Detection*

Pitch detection as in (4) and (5) is done by calculating the degree of neck flexion by using the *Head* joint and the *ShoulderCenter* joint (Fig. 2 and Fig. 3).

$$Pitch° = 90° - \left\{acos\left[\frac{\Delta Z}{r}\right] * 180/\pi\right\} \tag{4}$$

$$Pitch°_{Relative} = Pitch°_{Current} - Pitch°_{Base} \tag{5}$$

The system determines if the user's head is pitching as calculated in (6).

$$Pitch°_{Relative} \leq -10° \tag{6}$$

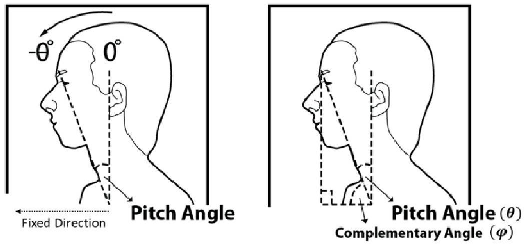

Fig. 2. Pitch Angle and Its Complementary Angle.

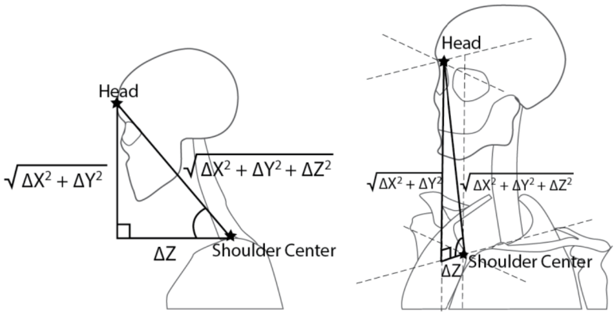

Fig. 3. Pitch Angle Translation in Kinect Coordinates.

2) *Twisted Posture Detection*

Twisted posture detection is used to detect when the user's body is not facing in the proper direction, which can result in several musculoskeletal muscle problems and bad eyestrain.

Facing angle as calculated in (7) and (8) uses the *ShoulderRight* joint and the *ShoulderLeft* joint (Fig. 4 and Fig. 5).

$$Facing^\circ = \left\{acos\left[\frac{\Delta Z}{r}\right] * 180/\pi\right\} - 90^\circ \qquad (7)$$

$$Facing^\circ_{Relative} = Facing^\circ_{Current} - Facing^\circ_{Base} \qquad (8)$$

The system determines if the user is twisting his or her body to the right as calculated in (9).

$$Facing^\circ_{Relative} \leq -15^\circ \qquad (9)$$

The system determines if the user is twisting his or her body to the left as calculated in (10).

$$Facing^\circ_{Relative} \geq +15^\circ \qquad (10)$$

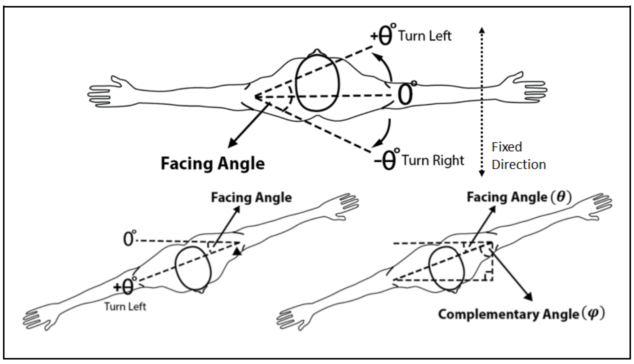

Fig. 4. Facing Angle and Its Complementary Angle.

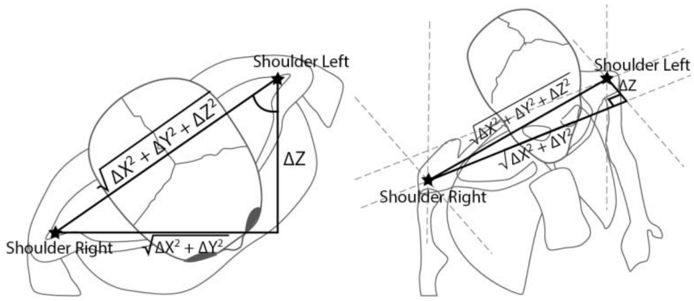

Fig. 5. Facing Angle Translation in Kinect Coordinates.

3) *Other Postural Detections*

The proposed system can also detect whether the user is sitting or standing, and whether the user is working or taking a break. Further information can be found in [1].

D. Noise Filtering

Skeleton data from Kinect can be adversely affected by interference and abrupt transitions in posture detection. To prevent this problem, we developed a technique using the idea of "Consensus" (Fig. 6). The same state must last for a set period of time before the system accepts that state. For example, when a user changes posture from non-pitching to pitching, the system will not determine that the user is pitching immediately, but it assumes that the user is pitching. Only if the following 30 frames (~1 second) detect and agree that the user is pitching, then the system will register the state of user as "pitching".

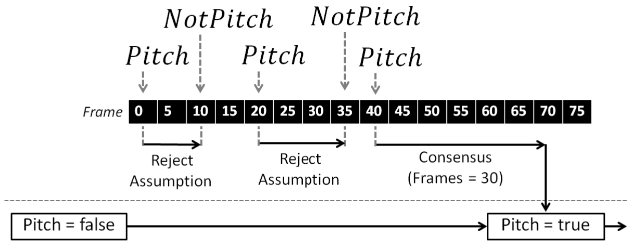

Fig. 6. State Transition & Noise Filtering.

V. ALARM AND REPORT

A. Health Risk Level

According to literature reviews on ergonomics, we have introduced the leveling system for justifying the state of health risk as follows:

- *Lv0* or *Green* : healthy state
- *Lv1* or *Yellow* : caution state
- *Lv2* or *Red* : unhealthy state

The health risk leveling system works by using the counter called "Risk Score". This leveling system is applied to monitor "Prolonged Sitting", "Pitch", and "Twisted Posture".

B. Total Risk Score and Total Health Risk Level

The total risk score is calculated using scores which are prolonged sitting, pitch, and twisted posture. An example is shown in Fig. 7.

Prolonged Sitting, risk score [0, 240]	= 143
Pitch, risk score [0, 120]	= 64
Twisted Posture, risk score [0, 120]	= 9
Normalizes data into the range of [0, 100]	
Prolonged Sitting, risk score [0, 100]	= 59.58
Pitch, risk score [0, 100]	= 56.67
Twisted Posture, risk score [0, 100]	= 7.50
Total Risk Score [0, 100]	**= 41.25**

Fig. 7. Calculation of Total Risk Score.

There are only three levels of health risk for prolonged sitting, pitch, and twisted posture, and the transition is cut over by the threshold value. However, a gradual transition for the total health risk level was preferable, so we applied the idea of membership function from fuzzy logic to smooth out the changes in the health risk level.

The leveling system of health risk can be plotted as shown in Fig. 8. The dashed lines represent risk scores from the example in Fig. 7. The membership of total health risk level is calculated by summing up the memberships of its components and then calculating the percentages as shown in Fig. 9.

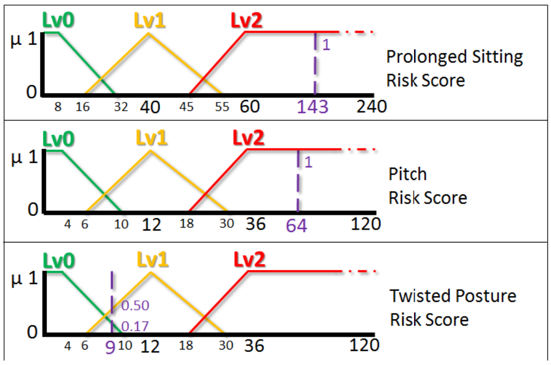

Fig. 8. Health Risk Level.

	Score	Membership		
		Lv0	Lv1	Lv2
Prolonged Sitting	143	0	0	1
Pitch	64	0	0	1
Twisted Posture	9	0.17	0.50	0
Total Health Risk	**40.69**	**0.17**	**0.50**	**2**
		6.37%	**18.73%**	**74.91%**

Fig. 9. Membership of Total Health Risk.

For visualization, the color of health risk for the given values will mix the colors of green 6.37%, yellow 18.73%, and red 74.91%. In an 8-bit RGB color model [20], red is represented by [255, 0, 0], yellow is [255, 255, 0], and green is [0, 255, 0]. Thus, the color mixing for health risk level will result in [(18.73% + 74.91%) * 255, (6.37% + 18.73%) * 255, 0] = [239, 64, 0] or EF4000 in hexadecimal, which is the vivid vermilion color [21] as shown in Fig. 10.

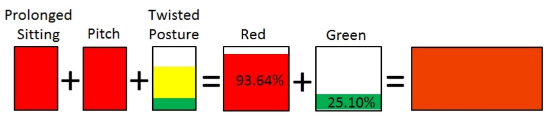

Fig. 10. Vivid Vermilion [239, 64, 0] Resulting from Color Mixing.

C. *Real-Time Feedback*

1) Monitoring Screen and In-App Alarm

The user can see results of the prolonged sitting and posture detection on a monitoring screen in the application as shown in Fig. 11. The application can alert the user using a pop-up message, voice message or alarm sound.

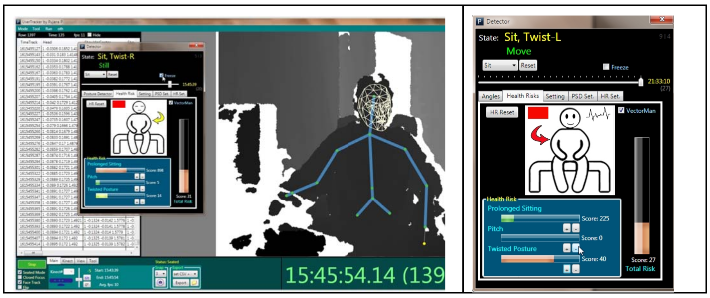

Fig. 11. Monitoring Screen and Posture Monitoring Dialog.

2) Alerting Device

"Pos-Monitor" (Fig. 12) was developed using microcontroller to provide a user-friendly interface for giving system feedback to the user. Pos-Monitor contains the following features:

- LED lights blink to attract the user's attention and show a warning message on the LCD monitor.
- Pos-Monitor can perceive what the user is doing. If the user corrects his or her posture when it suggests, it will thank the user for taking that action.
- Pos-Monitor contains a power-saving function. Whenever there is no message, the light of the LCD monitor will be off, and it automatically sleeps when the user walks out for a break.

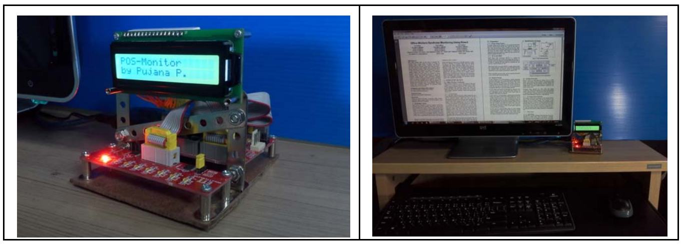

Fig. 12. Pos-Monitor.

D. *Summary Report*

We have introduced several techniques for visualizing the summary report with a selectable range of details. The objective is to make the system easy to use and to enhance user experience.

1) Detailed Summary

The first technique is shown in Fig. 13; symbols are used to indicate whether the user has performed a body movement such as pitched the neck, or turned the body in a specific period of time. The rows indicate health risk levels via background color and indicate risk scores by the line graphs. The user can zoom in and zoom out on specific points in the time frame, and the user can view the values by moving the cursor over the targeted area.

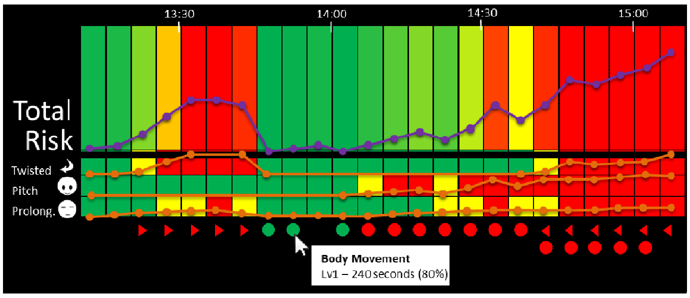

Fig. 13. Detailed Summary (Time Frame = 5 minutes).

2) *Short Summary*

In the short summary view, the amount of detail presented to the user is limited, to promote readability and ease of use. Vector man icons are used to represent body health risks (Fig. 14).

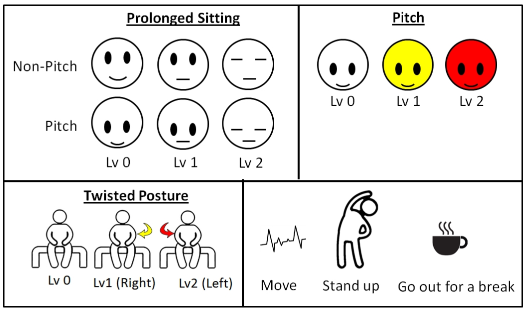

Fig. 14. Vector Man.

The short summary can be visualized as shown in Fig. 15; the background color represents the total health risk level and the line graph indicates its score during any period of time. Vector man icons are used to report the user's posture during that period; these icons are drawn only when there is a significant change in the posture or the total risk score (e.g. at the local maximum and minimum).

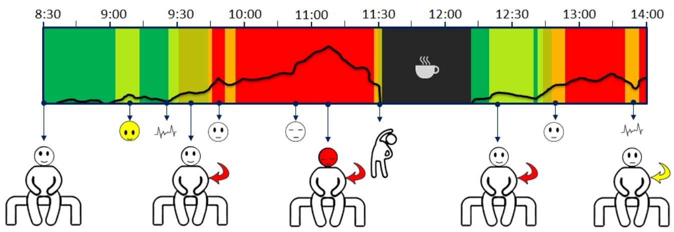

Fig. 15. Short Summary with Normal-size Icons.

3) *Posture Summary*

Posture Summary reports the time the user has spent in each posture (Fig. 16). The user can also view the percentage of health risk level for a specific type of posture on a pie chart, as shown in Fig. 17.

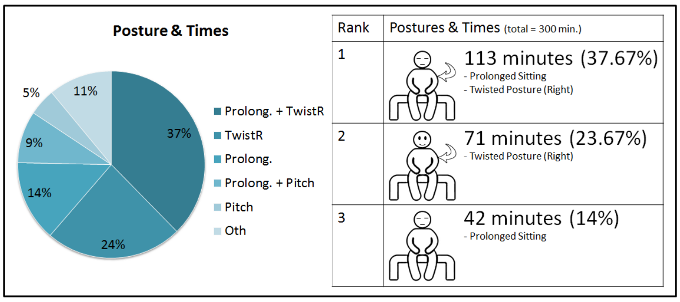

Fig. 16. Posture Summary.

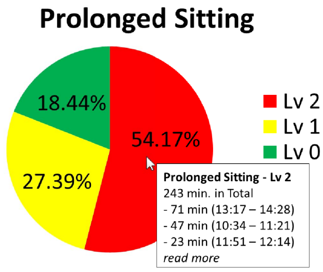

Fig. 17. Prolonged Sitting Risk Summary.

4) *Health Trend Summary*

The Health Trend Summary report shows the average health risk score of each day or each week. The line graph shows the user about the trend of their health risk, as shown in Fig. 18.

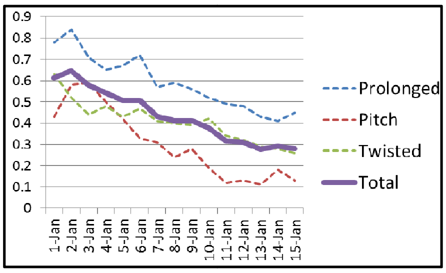

Fig. 18. Health Risk Trend for 15 days.

VI. Experiment and Results

A. *Posture Detection*

We have tested the system with 10 volunteers who gave their consent participate in the study. The testing was conducted at real working spaces to measure the system accuracy, usability, and level of user acceptance. For accuracy evaluation, we let the volunteers perform actions to see whether the system could detect them or not (100 times for each action). For usability and acceptance evaluation, the volunteers were asked to rate the system with scores ranging from zero to 10 and to provide open-ended recommendations for the system. Statistical methods were used to analyze the collected data.

From the system accuracy testing, we obtained the data as shown in Tab. 1.

Tab. 1: Accuracy Testing Data.

user	gender	height	Pitch	NotPitch	Twist1	Twist2	delta	NotTwist
1	M	178	100%	100%	96%	82%	**14%**	100%
2	M	178	93%	100%	98%	77%	**21%**	100%
3	F	155	97%	100%	94%	84%	**10%**	100%
4	M	175	92%	100%	93%	72%	**21%**	100%
5	F	170	96%	100%	95%	79%	**16%**	100%
6	F	150	100%	100%	94%	87%	**7%**	100%
7	M	180	92%	100%	91%	85%	**6%**	100%
8	M	173	84%	100%	83%	87%	**-4%**	100%
9	F	162	91%	100%	98%	90%	**8%**	97%
10	F	160	100%	100%	100%	91%	**9%**	100%
	Mean	**168**	**94.50%**	**100.00%**	**94.19%**	**83.40%**	**10.79%**	**99.70%**

Twist1 was the accuracy of twisted posture detection when the user twisted their body towards the Kinect camera direction; *Twist2* was the accuracy for the opposite direction, and delta was the difference of the accuracy rates (*Twist1 – Twist2*).

From one-sample t-test, we found that the accuracy of the twisted posture detection was affected by the position of the Kinect camera (system setup). For example, when the Kinect camera was placed to the front and right of the user, the system could detect the body right twisting (*Twist1*) better than the body left twisting (*Twist2*) by about 10.79%.

From an independent sample t-test, the accuracy rate of all posture detections did not depend on the system setup, user gender or the height of the user, except only the accuracy of *Twist2* which was affected by the system setup.

B. System Usability & Acceptance

The average scores out of 10 on *Usefulness, Ease-of-Use,* and *Satisfaction* are 9.40, 9.20, and 9.30 respectively. From an independent sample t-test, there are no differences in usability and acceptance of the system between male and female users.

VII. CONCLUSIONS AND FUTURE WORK

We have proposed a practical and affordable system using a Kinect camera for monitoring office worker's postures to reduce office workers syndrome. The proposed system performed data mining for prolonged sitting detection and used mathematics to translate human body angles for unhealthy posture detection. We had developed the user interfaces to provide system feedback, including a monitor screen, in-app alarm, and the alerting device. Finally, we introduced several visualization techniques for generating useful summary reports to the user.

The prototype had been tested in real working spaces. The system was reliable in various working environments; however, the accuracy of the twisted posture detection was affected by the position of the user and the Kinect camera. This was because some parts of the user's body were not clearly detected or were hidden from the camera's point of view. In order to solve this problem for future research, we suggest the use of multiple Kinect cameras.

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