# QUIT YOUR SLOUCHING! - USING WEARABLE SENSORS TO INVESTIGATE ENGINEERING LABORATORY WORK ERGONOMICS

**S. J. Suhonen**[1]
Tampere University of Applied Sciences
Tampere, Finland

**E.-L. Tuominen**
Tampere University of Applied Sciences
Tampere, Finland

***Conference Key Areas***: *Interdisciplinary education, Niche & Novel*
***Keywords***: *Laboraory, ergonomics, wearable sensors, posture, Upright Go*

## ABSTRACT

Laboratory engineering students have a lot of laboratory work in their curriculum. After graduation, they typically work in various laboratories as specialists conducting research and managerial tasks. Laboratory work sometimes means awkward working postures and prolonged times of holding hands in the air. To prevent work-related diseases and to lengthen work careers in the long run, good posture and good workplace ergonomics are important aspects.

In this study wearable posture sensors are used to investigate the ergonomics in two teaching laboratories: biochemistry and instrumental analysis laboratory. Volunteer students were asked to wear posture sensors (Upright Go) on their upper backs during the laboratory work for two weeks. The data consists of temporal distribution of the times of having a good posture and a slouching posture, respectively. Physiotherapy students participated in the study by monitoring the engineering students' working in the laboratory, making ergonomics mapping and interviewing students and teachers.

Preliminary results show that according to the wearable sensor data, there is a lot of variance in postures between individuals and somewhat between laboratories. On average, students were sloughed 45 % of the working time in biochemistry and 34 % in instrumental analysis laboratory. Some of them were sloughed even 75 % of the time. The height of the students varied between 150 cm and 188 cm. Thus, the same fixed workplaces are not well suited for everyone, especially in the biochemistry laboratory.

---

[1] *Corresponding Author*
*S. J. Suhonen*
*sami.suhonen@tuni.fi*

# 1 INTRODUCTION

## 1.1 Ergonomic problems

According to International Ergonomics Association (IEA), ergonomics is “the scientific discipline concerned with the understanding of interactions among humans and other elements. It is the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.” [1]. In Europe, the most common work-related problems caused by bad ergonomics are different musculoskeletal disorders (MSDs) [2]. In the United States, 45 % of Americans between the ages of 35 and 55 suffer acute back pain each year and it is the top cause of disability under the age of 45 in the US [3]. MSDs cause personal suffering and even early retirement, but they also cost businesses due to temporary assignments during sick leaves and due to reduced productivity. Nicholson et. al. [4] have conducted analysis of 29 cases in the UK and showed that the payback period of ergonomic interventions in those cases varied from just a couple of months to a few tens of months. Investments in reducing musculoskeletal risks had resulted in financial benefits to the companies through cost savings, increased productivity and quality of output. It should be noted, however, that cost-benefit analyses are difficult to conduct in the fields of health and safety and it is difficult to assign costs and benefits to ergonomics interventions.

Many factors affect the ergonomics at a certain work: Physical factors such as force application, repetition of movements, awkward and static postures; Organizational factors such as demanding work, low level of autonomy and monotonous work; Individual factors such as physical capacity and properties, age and prior medical history.

## 1.2 Laboratory work

In higher education institutions, the design of learning environments is based on pedagogical needs and principles. *Learning environment needs to be also authentic for the topic and field of engineering*. Thus in engineering, there is a need for laboratory spaces. However, the ergonomicis is not always high in the priority list when designing these spaces. Also the allowed budget sets boundaries for the planning and many needs have to be compromised.

Laboratory engineering students have a lot of laboratory work in their curriculum, even up to half of their studies. Also after graduation, they typically work in various research institutes, governmental laboratories, industrial laboratories, including the pharmaceutical, food, wood processing and chemical industry laboratories, as well as in environmental and life science research laboratories. To them, laboratory work sometimes means awkward working postures and for long periods of time. To prevent work-related musculoskeletal disorders and to lengthen work careers in the long run, good posture and good workplace ergonomics are important aspects for them. Both theoretical knowledge of good workplace ergonomics and practical own experience of it, not only help them themselves, but also benefit their whole work community when they work in managerial positions.

In this study, we concentrate on ergonomics in chemistry laboratory work in Tampere University of Applies Sciences from the physical factors point of view in two different laboratories: biochemistry (Fig. 1A) and instrumental analysis (Fig. 1B). In instrumental analysis lab, the students for example need to prepare the standard solutions and experimental samples and carry out analyses using different spectrometers and other intsruments, like HPLC, GC-MS, UV/Vis, TOC, AAS etc. In biochemistry lab, the working is more manual, less static, and contains a lot of precise hand working and pipeting in many consecutive sequences. Due to differences in working, these two laboratories were chosen for this research to have more complete view to ergonomics.

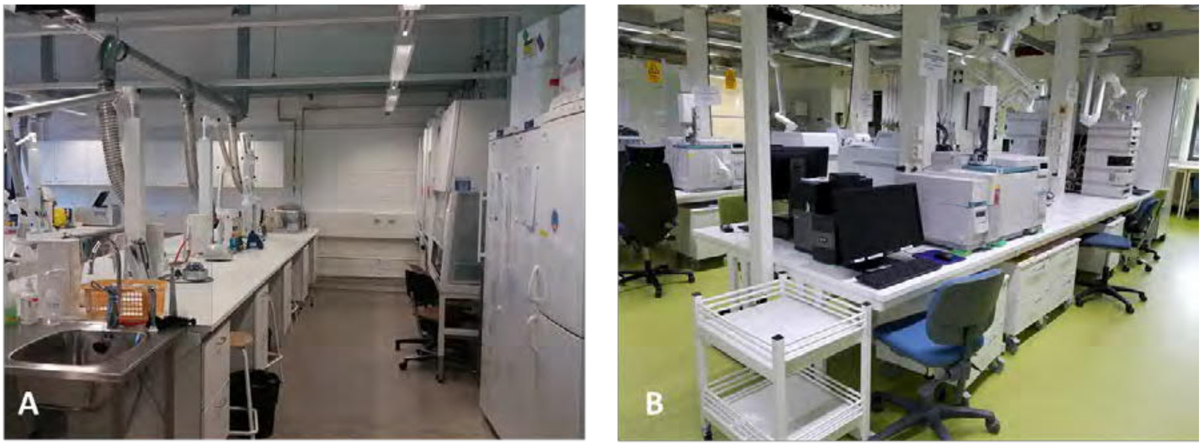


*Fig. 1. A) Biochemistry laboratory and B) Instumental analysis laboratory.*

### 1.3 Wearable posture sensors

Nowadays people are repetitively bending their heads over smart phones, handheld devices and laptops. This can lead to increased stresses in the cervical spine area and eventually to a “text neck” problem [6]. However, the development of wearable sensors and smart phone apps can also help in this same problem. There are several posture sensors on the market. The idea in posture sensors is to measure the tilt angle of upper back or neck and use it as a marker for bad/good posture. Many of the sensors have also a training mode, in which the sensor gives haptic feedback (e.g. vibrates) when the person is in slouched posture. In a pilot study by Zheng & Morrell, 100% of the subject persons sat in upright posture more often when there was haptic feedback than when there was not [5]. Additionally, when they turned the feedback off, all of the subjects continued to sit in upright or near-upright postures. Thus, haptic feedback seems to work well when training good posture for better ergonomics. Also Peper et. al. found that wearable posture feedback device helped participants to improve posture and decreased symptoms [7]

# 2 METHODOLOGY

## 2.1 Outline of this study

The main idea in this study was to observe the laboratory ergonomics in biochemistry and insrymental analysis laboratories. Naturally the students also got information about their own working in the laboratory from the ergonomics point of view. This was accomplished with three different methdos:

1) Laboratory engineering students were using wearable posture sensors during the laboratory work days for two weeks.
2) Students from physiotherapy degree program participated in the study by observing the working in the laboratories and carrying out ergonomics mapping of the laboratory spaces.
3) The laboratory engineering students, laboratory personnel and teachers were interviewed and the students surveyed with an online form about their experiences of the ergonomics and using wearable sensors.

## 2.2 Collecting sensory data

In this study, ”Upright Go” -posture sensors were used to investigate the ergonomics in two different chemistry laboratories in Tampere University of Applied Sciences. The volunteer students were asked to wear the wearable sensors during their laboratory work for two weeks. The students attached the sensors to the their upper backs with medical-grade silicone tape in the beginning of each laboratory work day (Fig. 2A). The students used their own smart phones to connect to the wearable sensor and to collect the data and sent the data to the researchers afterwards. Prior to the data collection, the sensors were calibrated while in good posture in the guidance of the physiotherapy students. Altogether there were 15 laboratory engineering students who volunteered to join in this research.

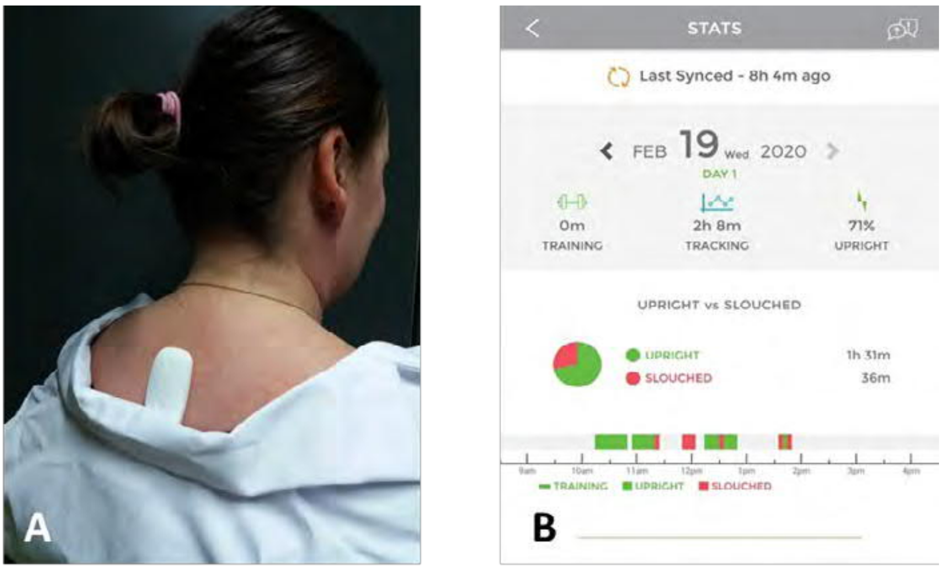


*Fig. 2. The sensor attached to upper back (A) and the view to data in “Upright Go”-app (B).*

The data consists of temporal distribution of the times of having a good posture and a slouching posture, respectively (Fig. 2B). The Upright Go app stores the time in slouched posture only after 3 min delay to allow movements etc. without recording them. It should be noted, that the initial positioning and calibration of the sensor affects all results and therefore these tasks were accomplished in guidance by the physiotherapy students. In this study, sensor's haptic deedback was turned off, because the main idea was to measure the posture and investigate the laboratory ergonomics, not yet train the students for better postures.

### 2.3 Interviews

While carrying out the ergonomic mapping of the laboratory spaces, the physiotherapy students also interviewed the students about their experiences of ergonomics. Afterwards a short online survey form was sent to the students who participated in this research. There were 8 answers (73 % of the participants) to the survey. All of the questions were open ended:

1. *"What do you think laboratory ergonomics means?"*
2. *"How did you experience this ergonomics research in general?"*
3. *"How did you experience using the Upright Go sensor?"*
4. *"From an ergonomic point of view, did you notice any differences between the intstrumental analysis lab and the biochemistry lab?"*
5. *" How would you like ergonomics to be taken into account in your studies in general and in your laboratory work in particular?"*
6. *"This study did not (yet) actually guide you to ergonomic work, but was this study already of any benefit to you yourself?"*

## 3 RESULTS

### 3.1 Posture sensor data

Figure 3 shows the sensor data of all laboratory working in the two different laboratories. Each horizontal bar represents one student visit to a laboratory. Some of the students worked more than one day in the labs during the research period and therefore there are more lines than volunteer students. The data bars are in random order. Clearly, there is a lot of variation between students, some showing upright posture almost all day long, whereas others had been in slouched posture most of the lab time. Especially in biochemistry labs there are some students who had spent most of the time slouched. In instrumental analysis lab, the situation is not quite as bad as in biochemistry lab.

The distributions of the times that students had spent in slouched posture in the two laboratories are presented in Fig. 4 as box-whisker plot. The same observation as before can be made here: In biochemistry lab students had spent more time in slouched posture, someone even over 200 minutes. This is remarkable part of the working time, which on average was 255 min in that laboratory.

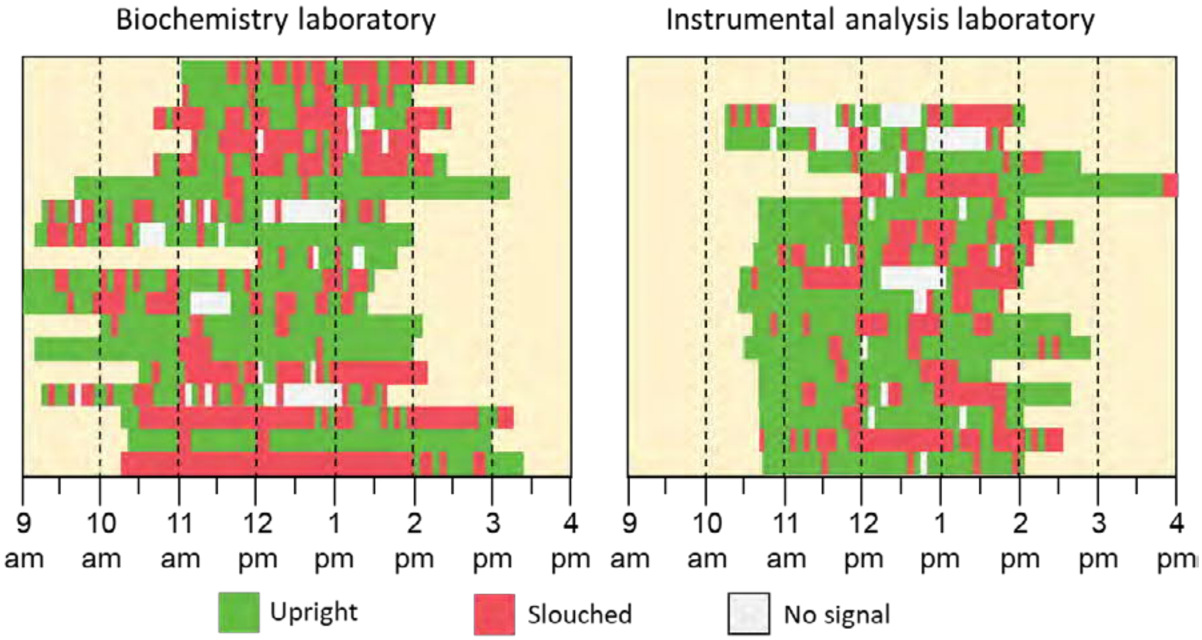


*Fig. 3. Sensor data of all laboratory working in the two different laboratories. Each horizontal bar represents one student visit to a laboratory.*

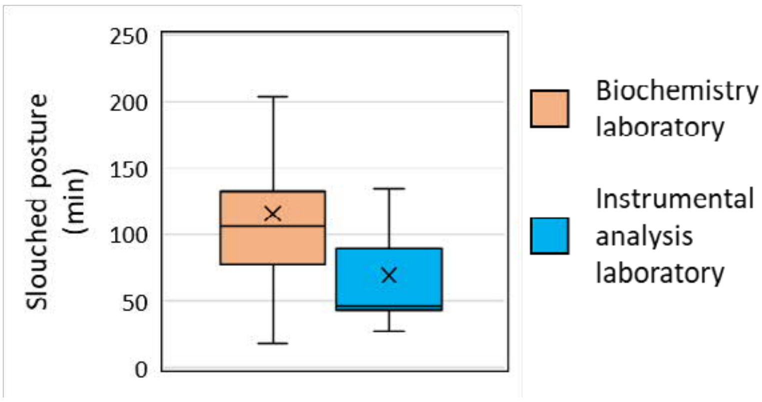


*Fig.4. Temporal distributions of the times students had spent in slouched posture in biochemistry laboratory and instrumental analysis laboratory.*

It can be speculated, that the posture is more likely to be slouched after long working time in the laboratory due to fatigue. If this was the case, then the sensor data wouldn't tell about the laboratory learning environment but rather about student tiredness. However, this can not be observed in Fig. 3. To investigate this further, a plot of slouched time percentage versus total laboratory working time was drawn. According to this graph (Fig. 5.) there is no correlation between the length of laboratory working time and slouching, neither in biochemistry nor in instrumental analysis laboratory, since the correlation coefficients are very low ($r$ = 0,09 and $r$ = 0,02. This supports the interpretation, that the slouching is caused by the laboratory work environment rather than fatigue.

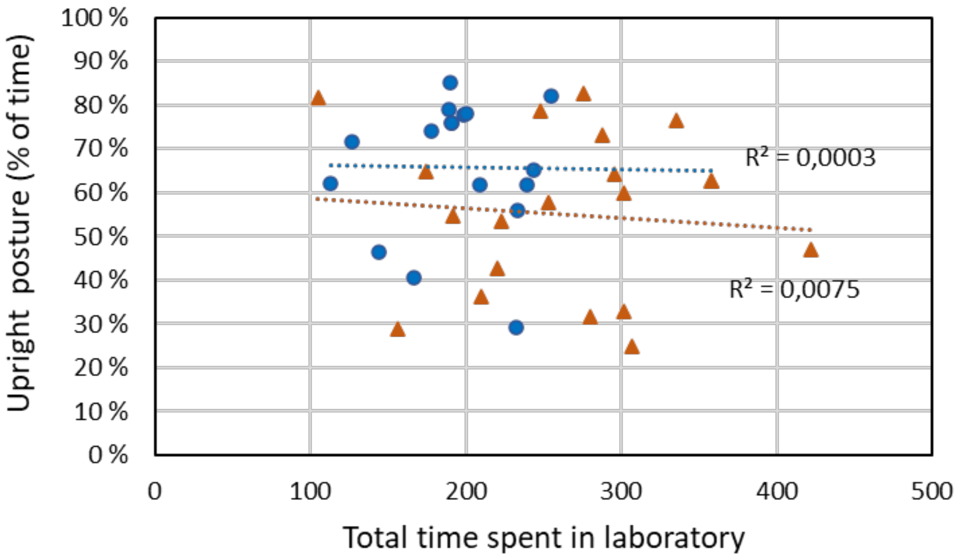


*Fig. 5. There is no correlation between upright posture and total time spent in laboratory.*

### 3.2 Ergonomic mapping, intreviews and survey

In the intreviews, many of students told about occasional pain in lower back and sholders. They told that the stools are not good and even the shorter students found the tables to be too low. According to the mapping done by the physiotherapy students, the tables were clearly too low for most of the students for standing work and the stools too high for sitting work for most students. The need for precise working leads easily to leaning forwards and tilting head (fig. 6A). Another problem arises with the fume hoods. There is no room for legs under the hoods which lead to very awckward postures (fig. 6B).

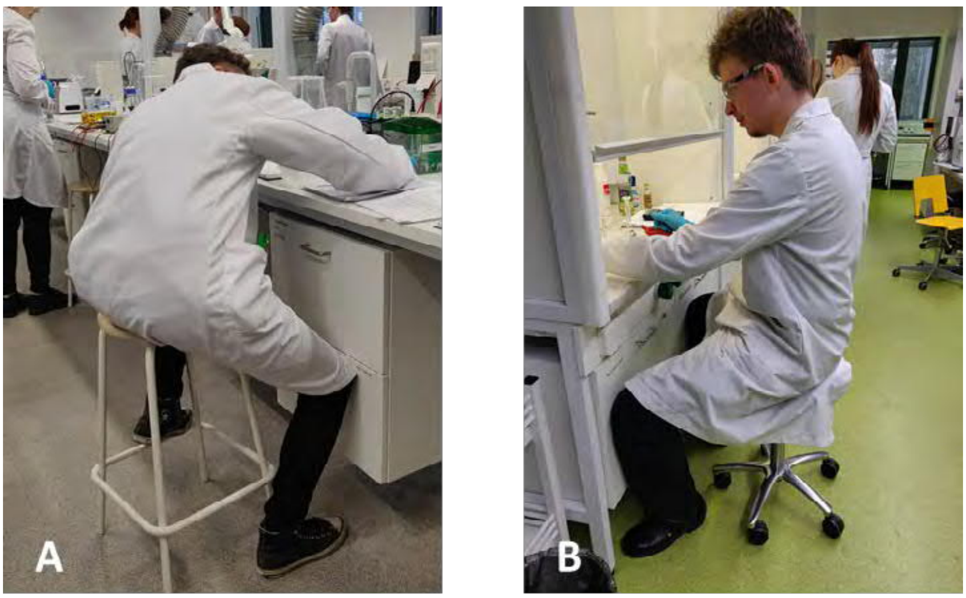


*Fig. 6. A) The tables are too low for standing work and the stools too high for sitting work for most students. The need for precise working leads easily to leaning forwards and tilting head. B) There is no room for legs under the fume hoods which lead to very awckward postures.*

According to the survey answers, all students found this ergonomics research to be interesting and important. Also the use of “Upright Go” -sensor was mostly found to be easy and undisturbing. Some students reported that in the beginning they were too aware of the sensors, which was somewhat annoying, but they forgot its presence after a while. Even though there was no posture training nor any ergonomics teaching for the students, all of the respondents answered that they already benefitted from the research by becoming more avare of their working posture and started to pay more attention to it. Here are a few picks from the student answers to the survey (translated to English):

> *”For the first time I started even to think about laboratory work ergonomics. For sure it would be necessary to pay more attention to it in the future.”*
>
> *“I hope that the different heights of students would be better taken into account. Electric tables would help. Ergonomics and its importance should be discussed more in the university.”*
>
> *“During this research project I have started to think about my working postures and how I could do the tasks with minimal physical strain.”*

## 4 SUMMARY AND ACKNOWLEDGMENTS

The Upright Go sensor was easy to use and students considered it undisturbing during the laboratory work. The initial positioning and calibration of the sensor is critical. The data revealed that many of the students worked prolonged times in sloughed postures. Thus, improvements need to be done both on the laboratory set-ups and furniture as well as in students working habits. The whole research also revealed, that laboratory work ergonomics is not well known by the students and they don’t pay much attention to it. In the future, some studies of ergonomics will be included in laboratory engineering curriculum. What comes to this research, in the next phase more volunteer students are needed for better statistics. Then the students can also be devided into experimental group and control group. The experimental group will then be trained for better postures and work ergonomics. By comparing their data with the data of control group, we hope to see the effectiveness of the training.

## REFERENCES

[1] International ergonomics association, What is Ergonomics?, available at: https://iea.cc/what-is-ergonomics/

[2] European Agency for Safety and Health at Work (2007). Introduction to work-related musculoskeletal disorders. Available at https://osha.europa.eu/en/publications/factsheet-71-introduction-work-related-musculoskeletal-disorders/view

[3] Wang, C. (2016). Good Posture and its Wealth of Benefits to the Workplace. Lumo Bodytech.

[4] Nicholson, A., Smith, C., & Mitchell, A. (2006). Cost-benefit studies that support tackling musculoskeletal disorders. Health and Safety Executive (HSE) (Vol. 491). Research report.

[5] Zheng, Y., & Morrell, J. B. (2010, March). A vibrotactile feedback approach to posture guidance. In 2010 IEEE haptics symposium (pp. 351-358). IEEE.

[6] Chronic Conditions Team, Cleveland Clinic (2015) Text Neck: Is Smartphone Use Causing Your Neck Pain? Healthessentials. Available at https://health.clevelandclinic.org/2015/03/text-neck-is-smartphone-use-causing-your-neck-pain/

[7] Peper, E., Harvey, R., and Mason, L. (2019) “Don’t Slouch!” Improve Health with Posture Feedback, online journal, available at https://www.researchgate.net/publication/337424599_Don't_slouch_Improve_health_with_posture_feedback