MIE439: Project Proposal (Group 3)

A study of ergonomic strain injury risk considering human factors of standing and sitting workstations

24 February 2014

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Andrew Wong

Mohammad Saleh

Simeon Wong

Introduction

It is generally accepted that a sedentary lifestyle can lead to numerous health issues [1], [2], including breast and colon cancers, diabetes, and ischaemic heart disease [2]. Indeed, physical inactivity is associated, independent of Body Mass Index (BMI), with a greatly elevated any-cause risk of mortality [3]. Although prior studies have been mixed on associations between occupational sitting and health issues [4], [5], recent studies have shown statistically significant associations between both occupational and leisure sitting with physical cardio-metabolic risk factors [6], and mental psychological distress [7]. As such, there has been a recent push for further study of workspace sitting, especially in the use of, and the effects of stand-sit workstations [8]–[10]. However, the majority of the studies have focused on statistical health outcomes and acceptability and usability [8] of stand-sit workstations.

Significance

Given the increasing interest in standing workstations, it is important to ensure that no long-term adverse effects ensue from their prolonged usage. There is a gap in knowledge of the biomechanical implications and ergonomics of these workstations, especially considering human factors. The increased fatigue from prolonged standing may result in poor posture such as slouching [11], which would negate the potential cardio-metabolic and mental health benefits. The further study of the biomechanics and ergonomics of stand-sit workstations with regards to human factors is therefore both relevant and imperative.

Objectives

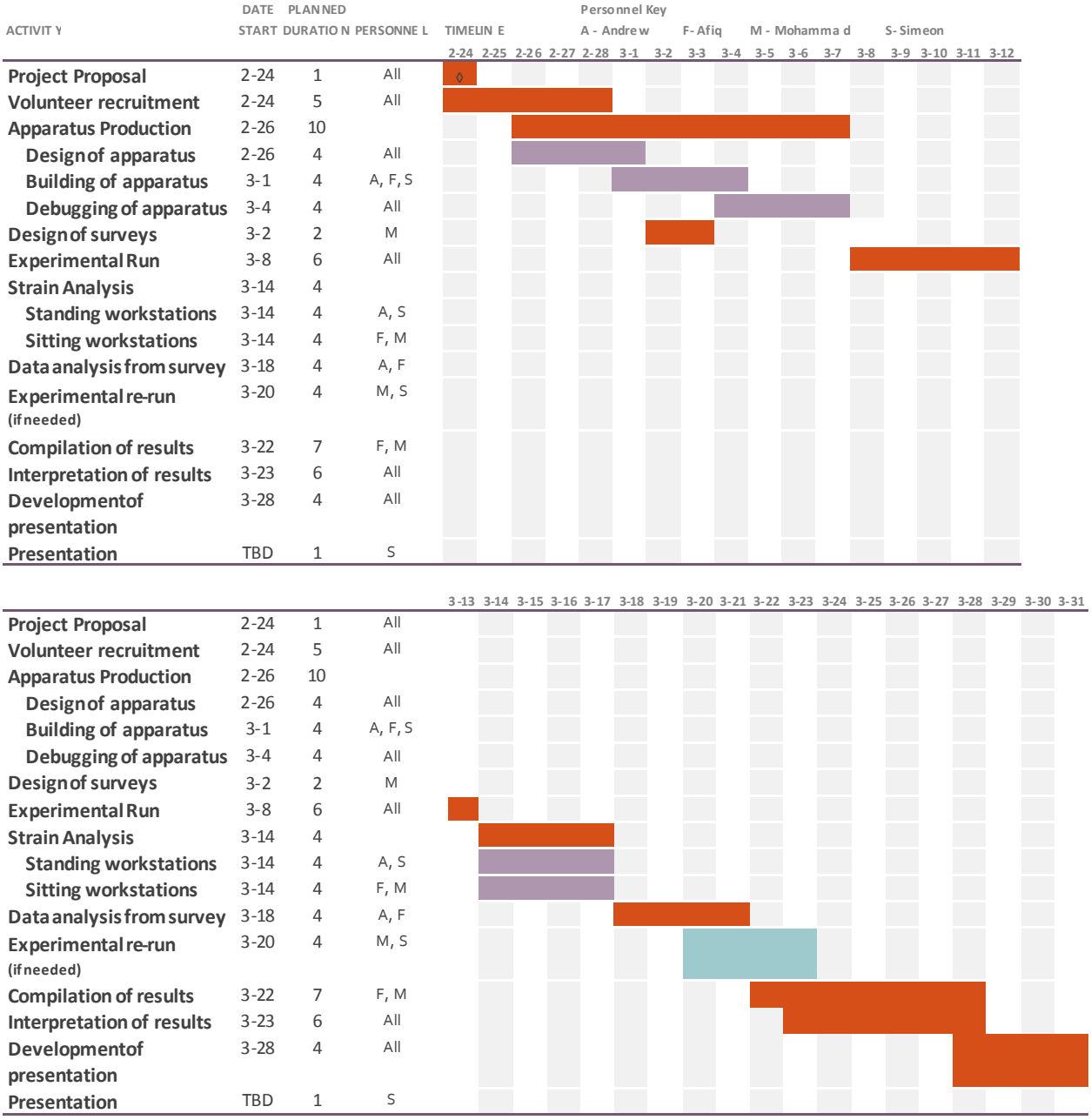
We propose to conduct a quantitative study of: (1) the association of spinal strain injury risk with posture; and (2) of comfort with ergonomics in the context of standing and sitting workstations.

Methods

The proposed study will involve two groups who are asked to use either a standing desk or sitting desk while maintaining specific postures. A Nintendo Wii Balance Board will be used to measure the center of mass (COM), with a pair of accelerometers positioned at the thoracic and lumbar spine areas to determine the inclination and torsion of the spine for (1). Using methods devised by [12], the body centre of gravity (COG) can be determined from the COM and the spine inclination. This data can then be used to infer postures and long-term strain on the spine, resulting in risk for strain injury, using methods given by the ISO 11226 and DIN EN 1005-4 standards.

For objective 2, comfort will be assessed subjectively by asking participants to rate the comfort of different standing/sitting postures on a numerical scale, adapted from Corlett's Part Discomfort [13], Shackel's General Comfort Rating [14], and Helander's Discomfort/Comfort Descriptors [15], and compared to the subjects' natural posture, acting as a negative control. Additionally, tracking the frequency of posture shifts during tests can yield a subject-specific measure of comfort, briefly, in general the more often a subject deviates from the test case's prescribed posture, the less comfortable the posture [16].

Milestones



ACTIVIT Y	DATE START	PLANNED DURATIO N	PERSONNE L
Project Proposal	2-24	1	All
Volunteer recruitment	2-24	5	All
Apparatus Production	2-26	10	
Design of apparatus	2-26	4	All
Building of apparatus	3-1	4	A, F, S
Debugging of apparatus	3-4	4	All
Design of surveys	3-2	2	M
Experimental Run	3-8	6	All
Strain Analysis	3-14	4	
Standing workstations	3-14	4	A, S
Sitting workstations	3-14	4	F, M
Data analysis from survey	3-18	4	A, F
Experimental re-run (if needed)	3-20	4	M, S
Compilation of results	3-22	7	F, M
Interpretation of results	3-23	6	All
Development of presentation	3-28	4	All
Presentation	TBD	1	S

Table 1: Gantt chart of proposed project timeline. Orange: milestone, purple: sub-milestone, blue: optional.

References

[1] *Global recommendations on physical activity for health*. World Health Organization, 2010.

[2] C. Mathers, G. Stevens, and M. Mascarenhas, *Global health risks: mortality and burden of disease attributable to selected major risks*. World Health Organization, 2009.

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[4] J. G. Z. van Uffelen, J. Wong, J. Y. Chau, H. P. van der Ploeg, I. Riphagen, N. D. Gilson, N. W. Burton, G. N. Healy, A. a Thorp, B. K. Clark, P. a Gardiner, D. W. Dunstan, A. Bauman, N. Owen, and W. J. Brown, "Occupational sitting and health risks: a systematic review.," *Am. J. Prev. Med.*, vol. 39, no. 4, pp. 379–88, Oct. 2010.

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[6] M. Saidj, T. Jørgensen, R. K. Jacobsen, A. Linneberg, and M. Aadahl, "Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study.," *PLoS One*, vol. 8, no. 8, p. e70213, Jan. 2013.

[7] M. Kilpatrick, K. Sanderson, L. Blizzard, B. Teale, and A. Venn, "Cross-sectional associations between sitting at work and psychological distress: Reducing sitting time may benefit mental health," *Ment. Health Phys. Act.*, vol. 6, no. 2, pp. 103–109, Jun. 2013.

[8] A. C. Grunseit, J. Y.-Y. Chau, H. P. van der Ploeg, and A. Bauman, "'Thinking on your feet': A qualitative evaluation of sit-stand desks in an Australian workplace.," *BMC Public Health*, vol. 13, no. 1, p. 365, May 2013.

[9] A. Radas, M. Mackey, A. Leaver, A. Bouvier, J. Y. Chau, D. Shirley, and A. Bauman, "Evaluation of ergonomic and education interventions to reduce occupational sitting in office-based university workers: study protocol for a randomized controlled trial," *Trials*, vol. 14, no. 1, p. 330, Jan. 2013.

[10] G. C. Ryde, H. E. Brown, G. M. E. E. Peeters, N. D. Gilson, and W. J. Brown, "Desk-based occupational sitting patterns: weight-related health outcomes.," *Am. J. Prev. Med.*, vol. 45, no. 4, pp. 448–52, Oct. 2013.

[11] C. J. Snijders, P. F. G. Hermans, R. Niesing, G. Jan Kleinrensink, and A. Pool-Goudzwaard, "Effects of slouching and muscle contraction on the strain of the iliolumbar ligament.," *Man. Ther.*, vol. 13, no. 4, pp. 325–33, Aug. 2008.

[12] O. Caron, B. Faure, and Y. Brenière, "Estimating the centre of gravity of the body on the basis of the centre of pressure in standing posture," *J. Biomech.*, 1997.

[13] E. N. Corlett, "Background to sitting at work: research-based requirements for the design of work seats.," *Ergonomics*, vol. 49, no. 14, pp. 1538–46, Nov. 2006.

[14] B. Shackel, K. D. Chidsey, and P. Shipley, "The assessment of chair comfort.," *Ergonomics*, vol. 12, no. 2, pp. 269–306, Mar. 1969.

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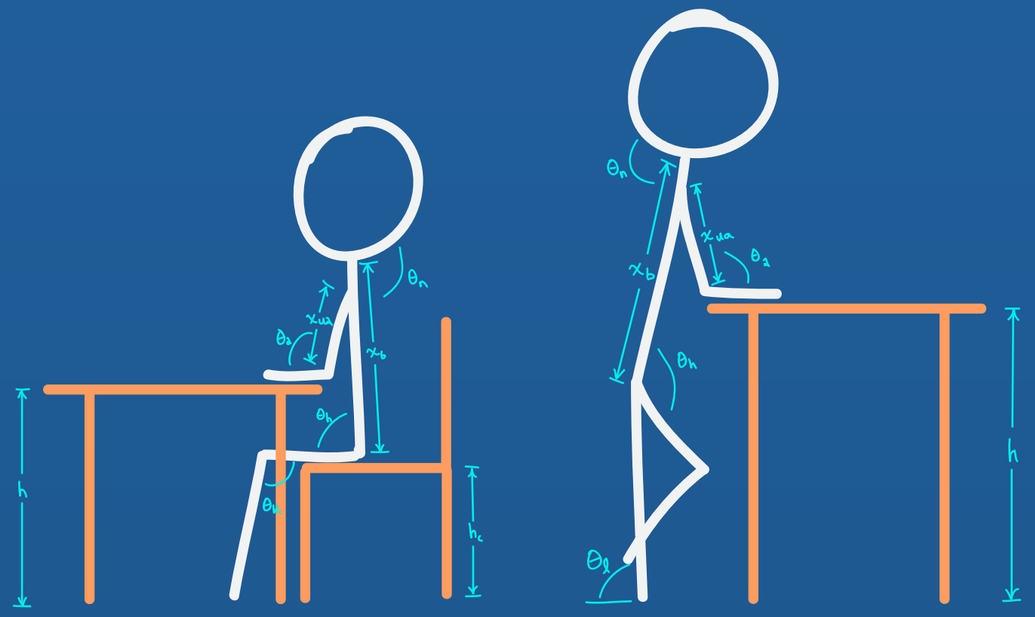


A study of ergonomic strain injury risk considering human factors of standing and sitting workstations

Afiq Asri, Mohammad Saleh, Andrew Wong, Simeon Wong

What are standing desks?

Why standing desks?

Background

Methods & Data collection

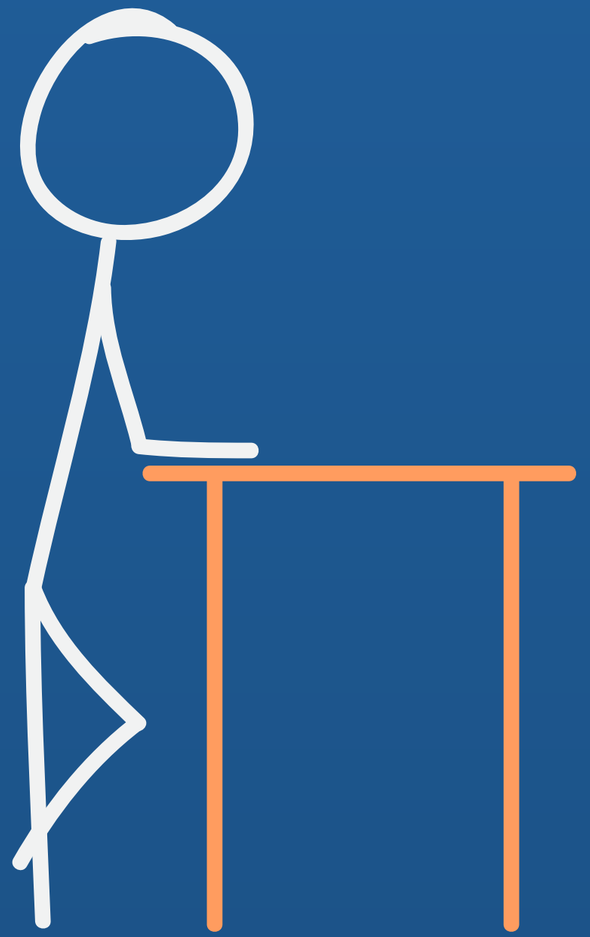
Analysis of results

Implications

Experiment

Standing desks are…

- Desks designed to be used for people who are standing
- Adjustable to the user's height
- Different styles



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Standing desks are…

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- Adjustable to the user's height
- Different styles

Standing desks have reported health benefits

- burning calories

  Christopher Reiff, Kara Marlatt and Donald R. Dengel. Difference in Caloric Expenditure in Sitting Versus Standing Desks. Journal of Physical Activity and Health, 2012, 9, 1009-1011.

- reduce varicose vein risk

  F Tuchsen, H Hannerz, H Burr, and N Krause. Prolonged standing at work and hospitalisation due to varicose veins: a 12 year prospective study of the Danish population. Occup Environ Med. Dec 2005; 62(12): 847–850.

- higher metabolism

  Healy, G. N. et al. 2008. "Breaks in sedentary time: beneficial associations with metabolic risk." Diabetes Care 31: 661-666.

Excessive sitting incurs health risk

- Sedentary lifestyle linked to many health issues and elevated mortality risk
  - Breast and colon cancer
  - Diabetes
  - Ischaemic heart disease

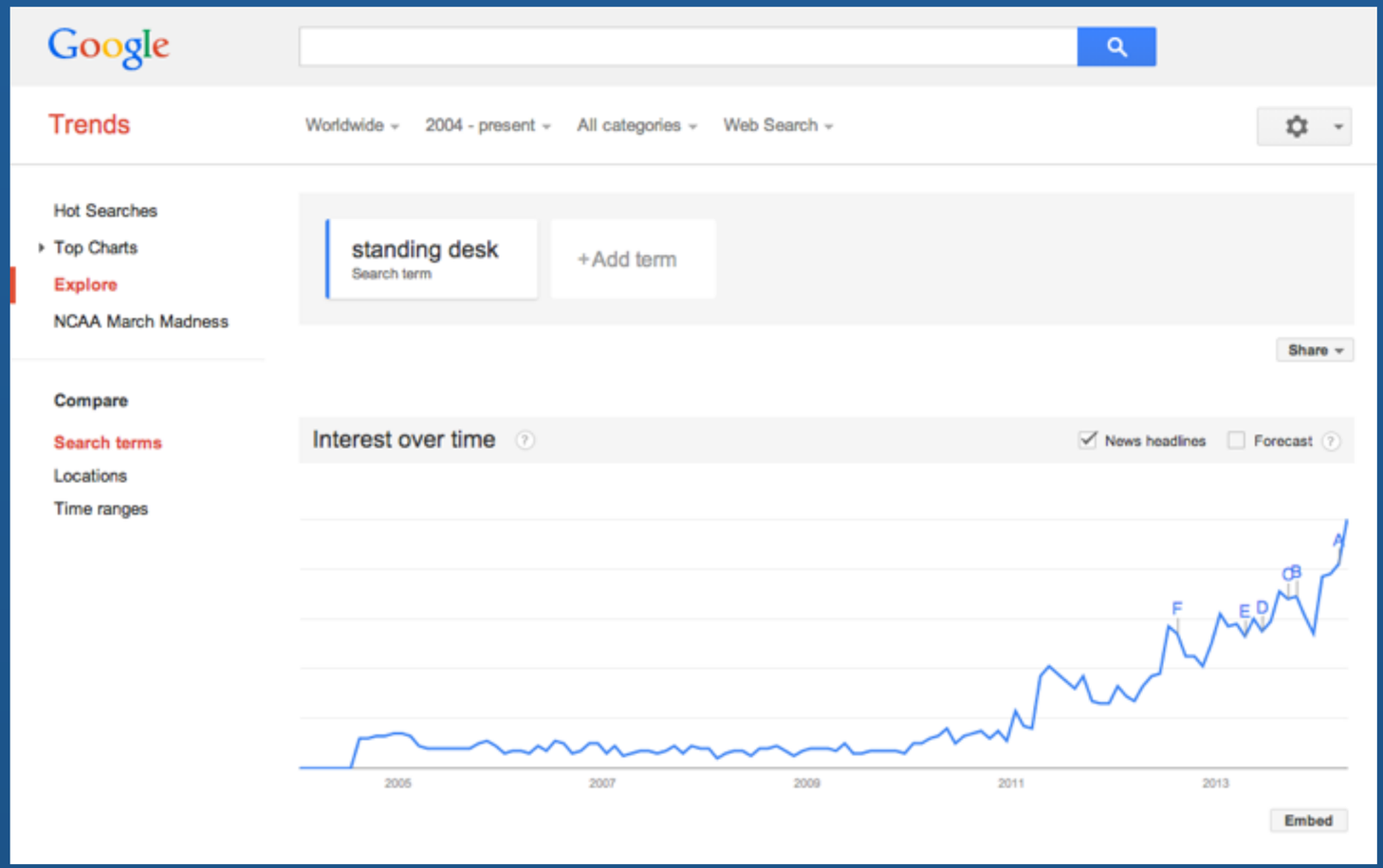
Excessive sitting incurs health risk

Studies have shown statistically significant associations between both occupational and leisure sitting with physical cardio-metabolic risk factors, and mental psychological distress.

- van Uffelen et al, Am. J. Prev. Med., 2010. vol. 39, no. 4, pp. 379–88
- Stamatakis et al, PLoS One, 2013. vol. 8, no. 9, p. e73753.
- Saidj et al, PLoS One, 2013. vol. 8, no. 8, p. e70213.
- Kilpatrick et al. Ment. Health Phys. Act., 2013. vol. 6, no. 2, pp. 103–109.

Standing desks are gaining popularity

- Rising interest in standing desks
- Facebook, Google offering employees the option of standing desks



Many occupations already require standing

- Cashiers
- Nurses
- Speakers (podiums)
- Draftsmen
- Flight Attendants
- Restaurant Employees
- Kitchen staff
- Lab researchers

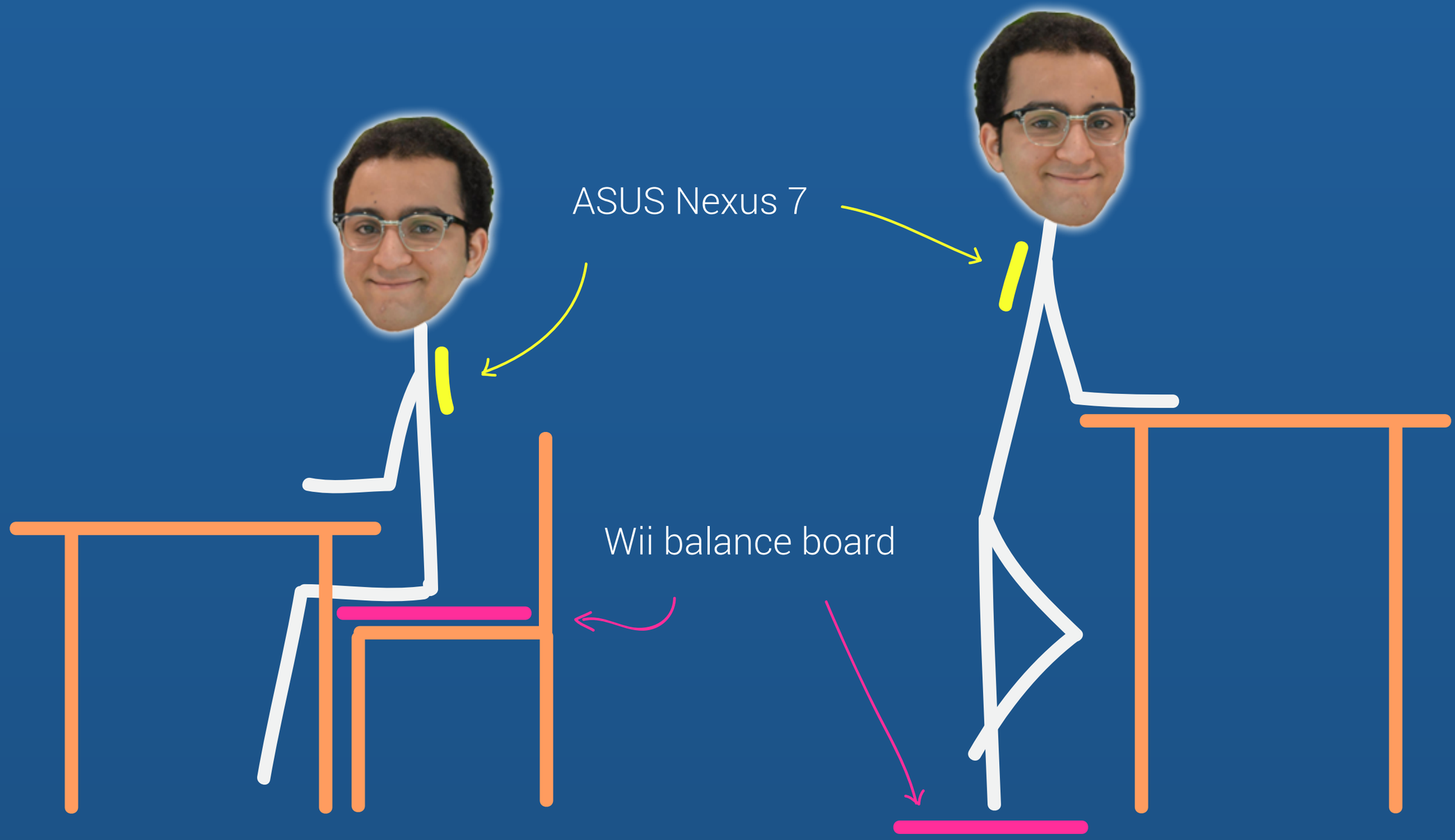
How comfortable are the use of standing desks?

How ergonomic are standing desks, compared to sitting?

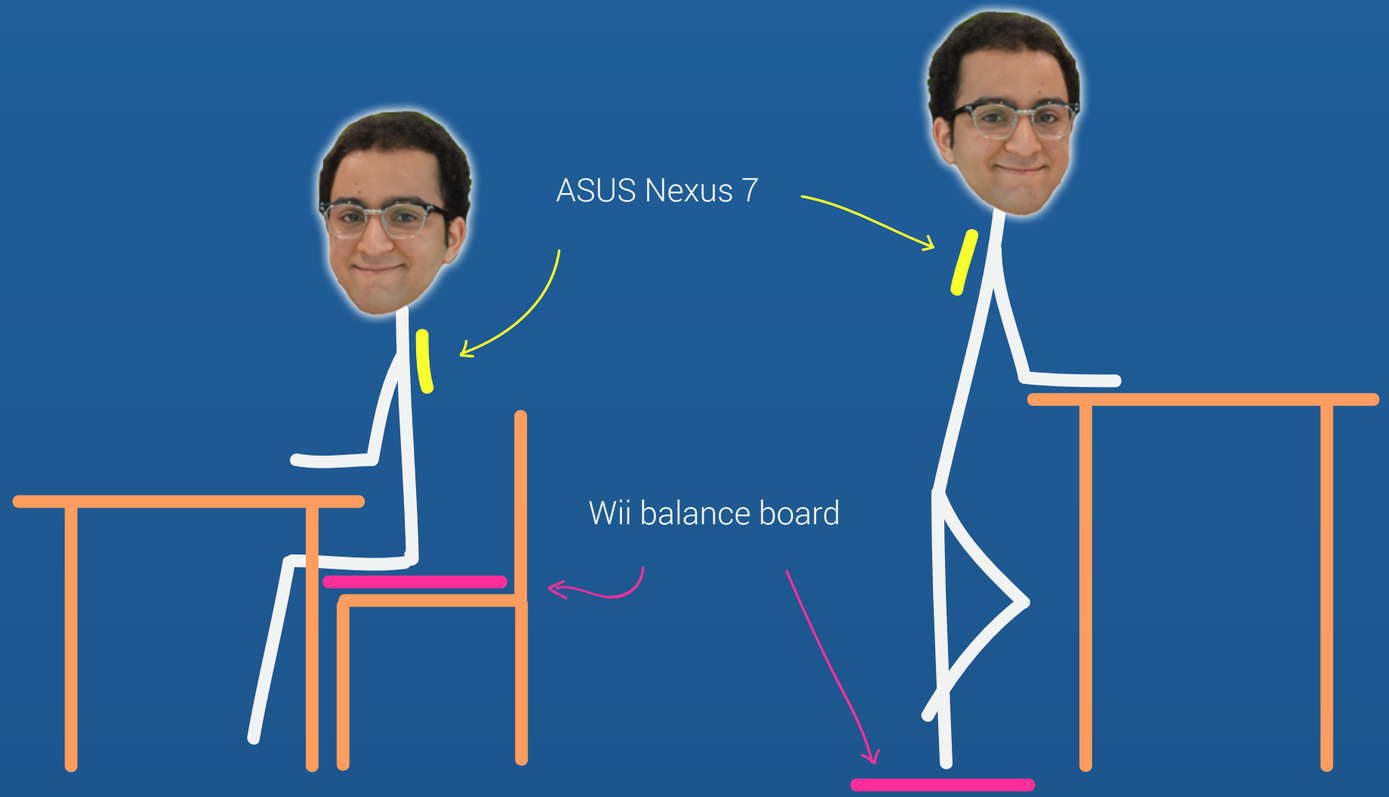
Will any increase in fatigue result in poor and detrimental posture?

Experimental Methods

Methods: Schematic

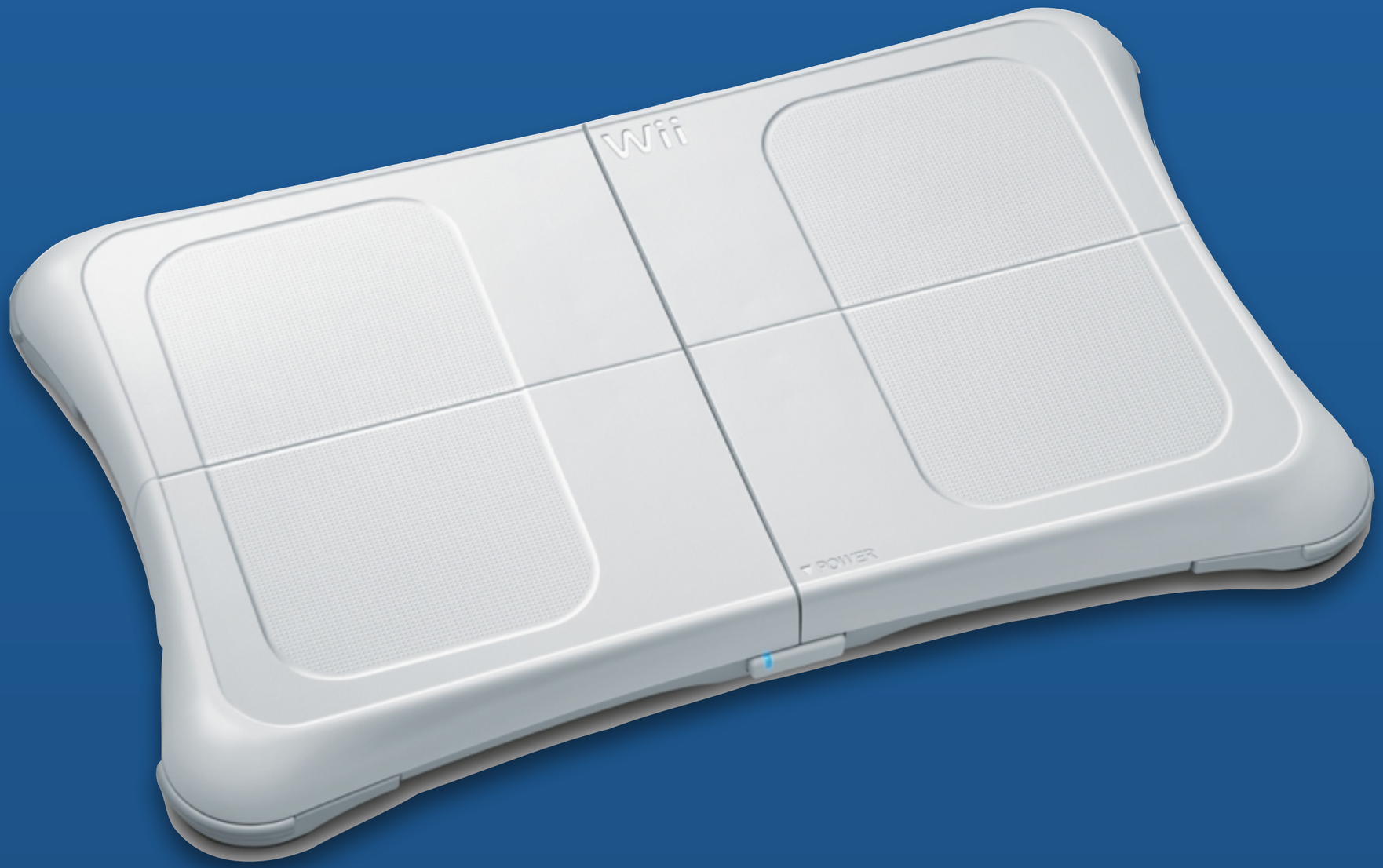


Methods: Schematic



Participants were asked to sit or stand on the balance board for an hour in a classroom setting.

Methods: Force Plate



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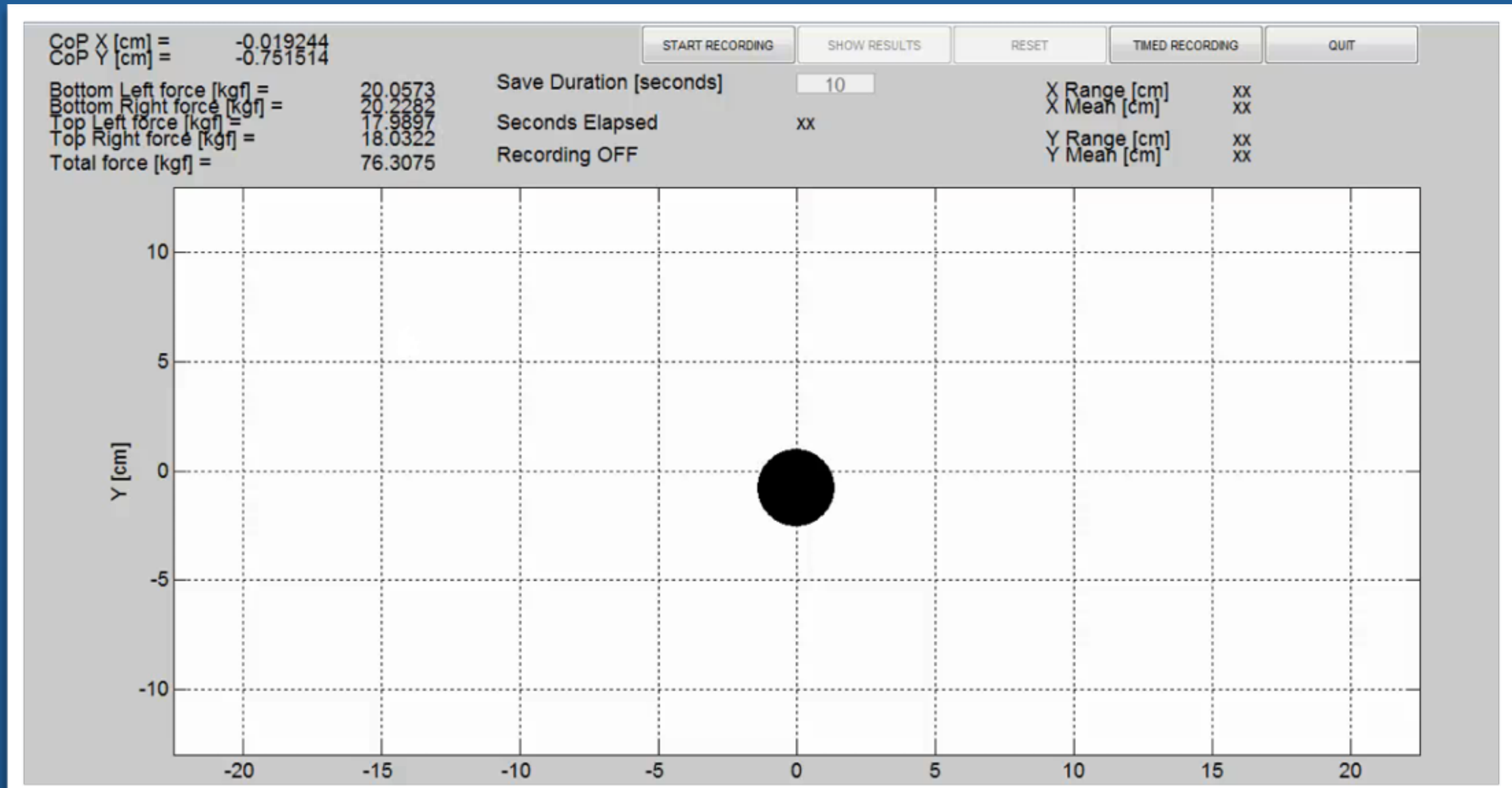
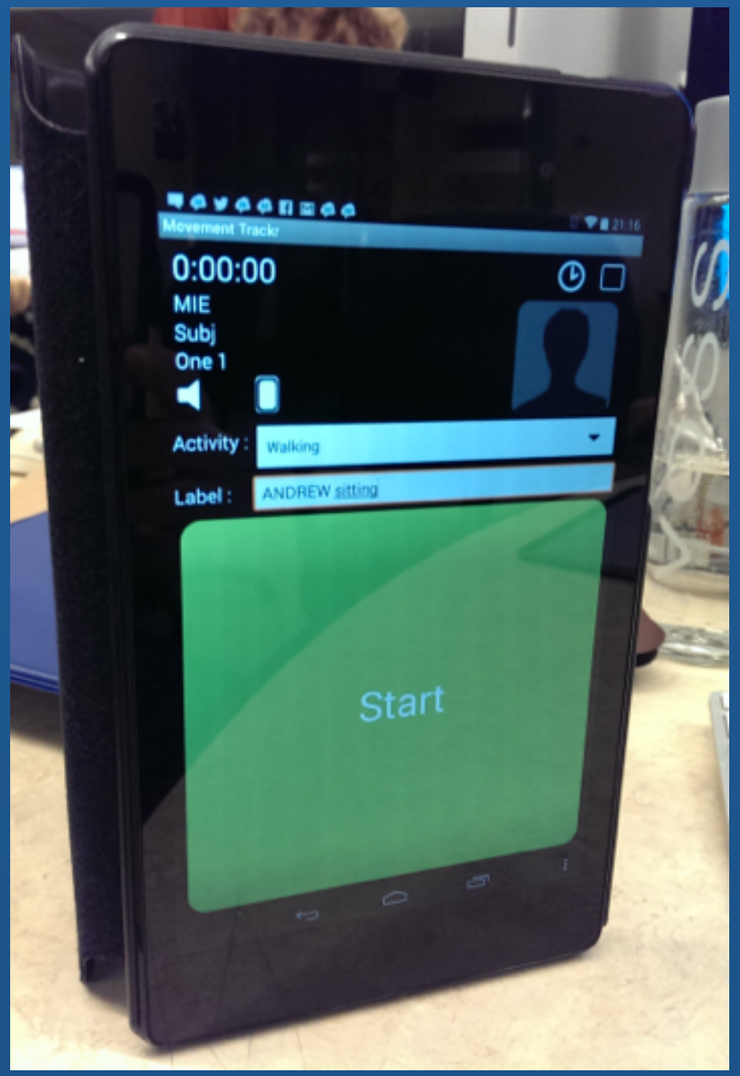
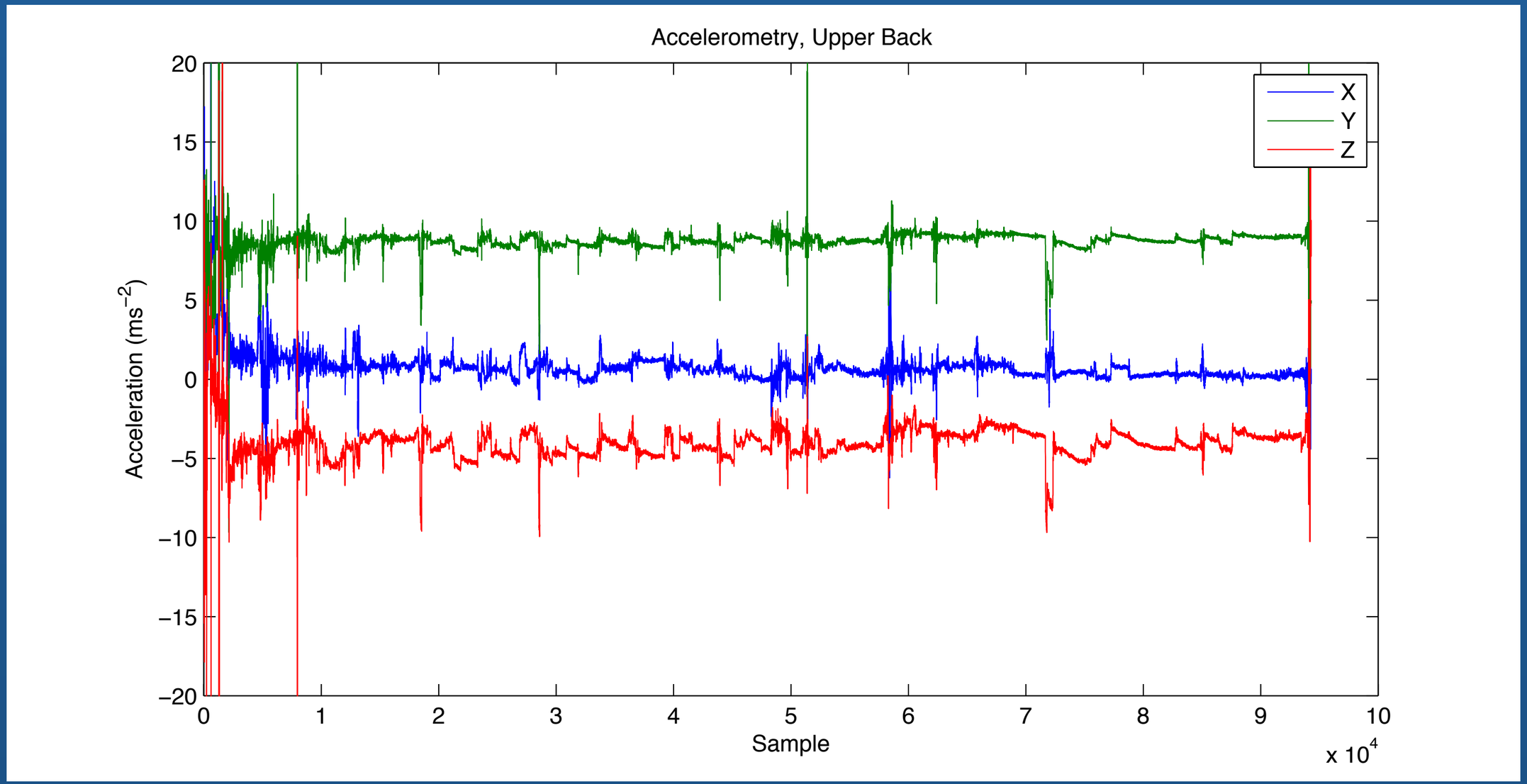


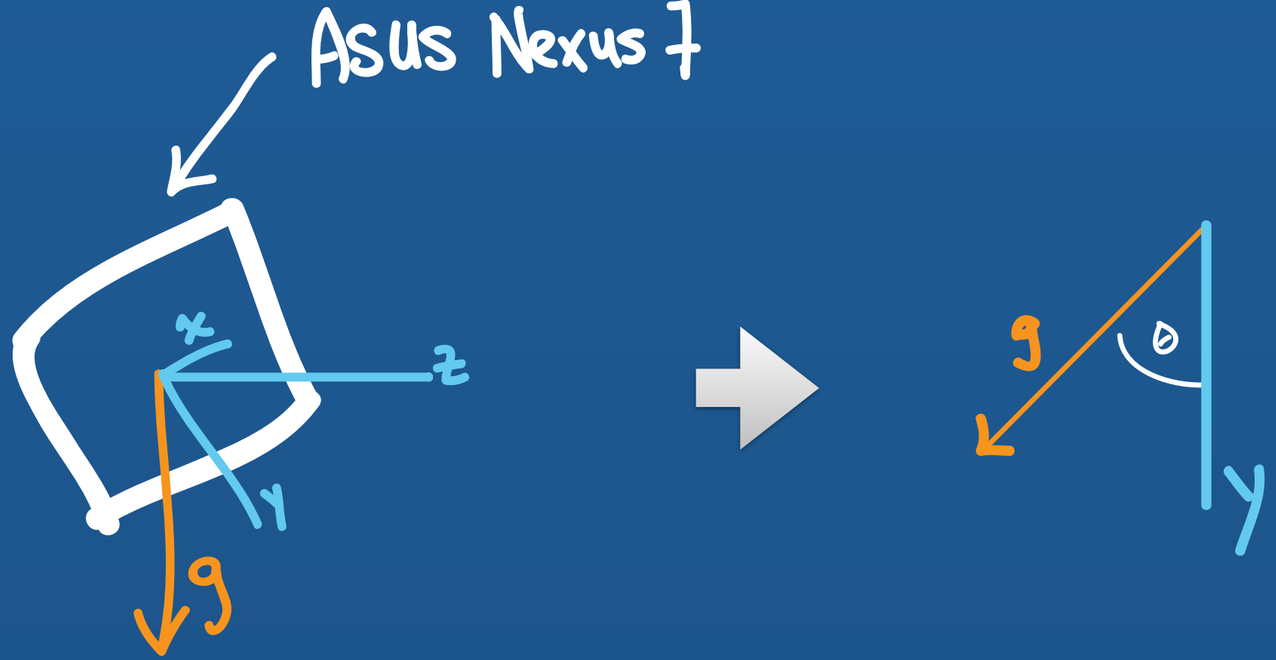
Methods: Accelerometry



Methods: Raw Accelerometry Data



Methods: Determination of back angle



$$\text{proj}_{\hat{y}}\ \vec{g} = |\vec{g}|\cos\theta$$

Methods: Self-reported comfort levels

- Then asked to report their comfortability using a survey
- Survey developed based on Corlett's, Shackel's and Helander's Comfort Rating

Methods: Self-reported comfort levels

Sitting vs Standing Desk: Survey

→ I am a ____ year old { female / male } who { owns / does not own } a standing desk. I { have / do not have } any prior back pain problems.

→ My current comfort level is:

Extremely comfortable 1 2 3 4 5 6 7 **Extremely uncomfortable**

→ Choose one of the following:

- I feel completely relaxed
- I feel perfectly comfortable
- I feel quite comfortable
- I feel barely comfortable
- I feel uncomfortable
- I feel restless and fidgety
- I feel cramped
- I feel stiff
- I feel numb (or pins and needles)
- I feel sore and tender
- I feel unbearable pain

→ Arrange the following regions in order from least painful to most painful. Only include regions where pain is felt:

Least painful Most painful

Order: _____

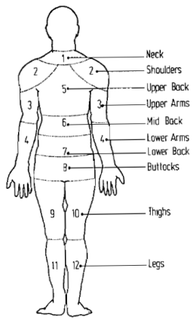


Figure 3. Body regions.

For each of the regions where pain is felt, rate the pain level from bearable pain (1) to unbearable pain (7):

Neck:	1	2	3	4	5	6	7	n/a
Shoulders:	1	2	3	4	5	6	7	n/a
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Lower arms:	1	2	3	4	5	6	7	n/a
Upper back:	1	2	3	4	5	6	7	n/a
Mid-back:	1	2	3	4	5	6	7	n/a
Lower back:	1	2	3	4	5	6	7	n/a
Buttocks:	1	2	3	4	5	6	7	n/a
Thighs:	1	2	3	4	5	6	7	n/a
Legs:	1	2	3	4	5	6	7	n/a

→Choose all that apply:

- ☐ I have sore muscles
- ☐ I have heavy legs
- ☐ I feel stiff
- ☐ I feel tired
- ☐ I feel pain
- ☐ I feel numb
- ☐ I feel uneven pressure
- ☐ I feel cramped
- ☐ I feel restless
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- ☐ I feel restful
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- ☐ Workspace feels comfortable
- ☐ I like the workspace

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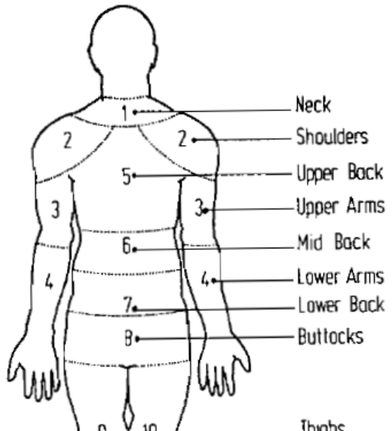

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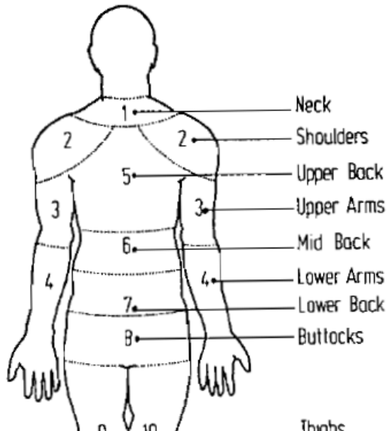

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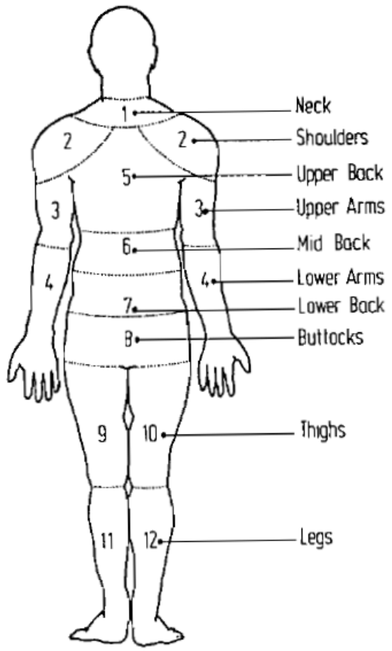

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- ☐ Workspace is spacious
- ☐ Workspace feels comfortable

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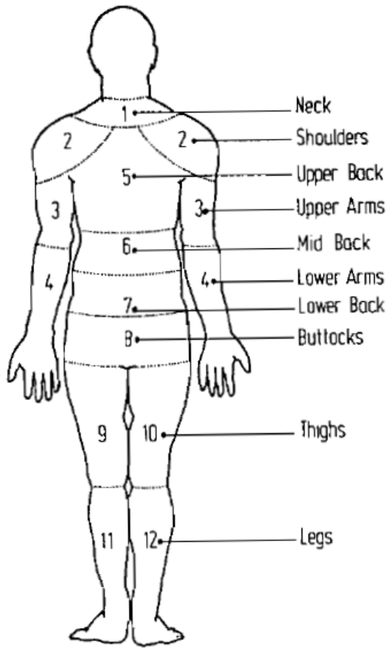

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- ☐ I like the workspace

Summary of Results

ISO11226 gives allowable postures

ISO11226 and DIN EN 1005-4 are equivalent international standards for workplace ergonomics to prevent chronic adverse risk factors.

Gives appropriate posture, position, and other factors.

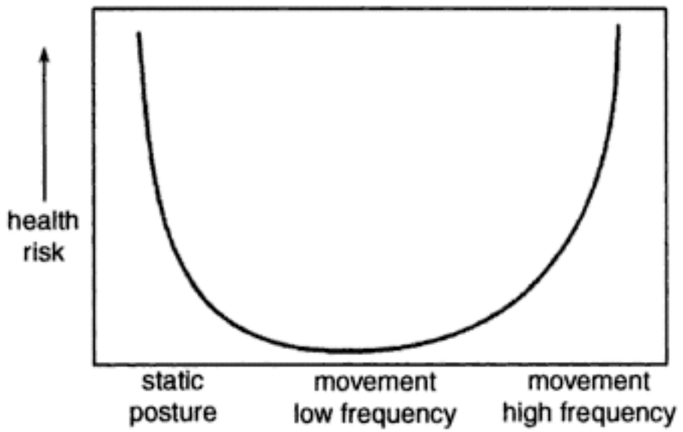
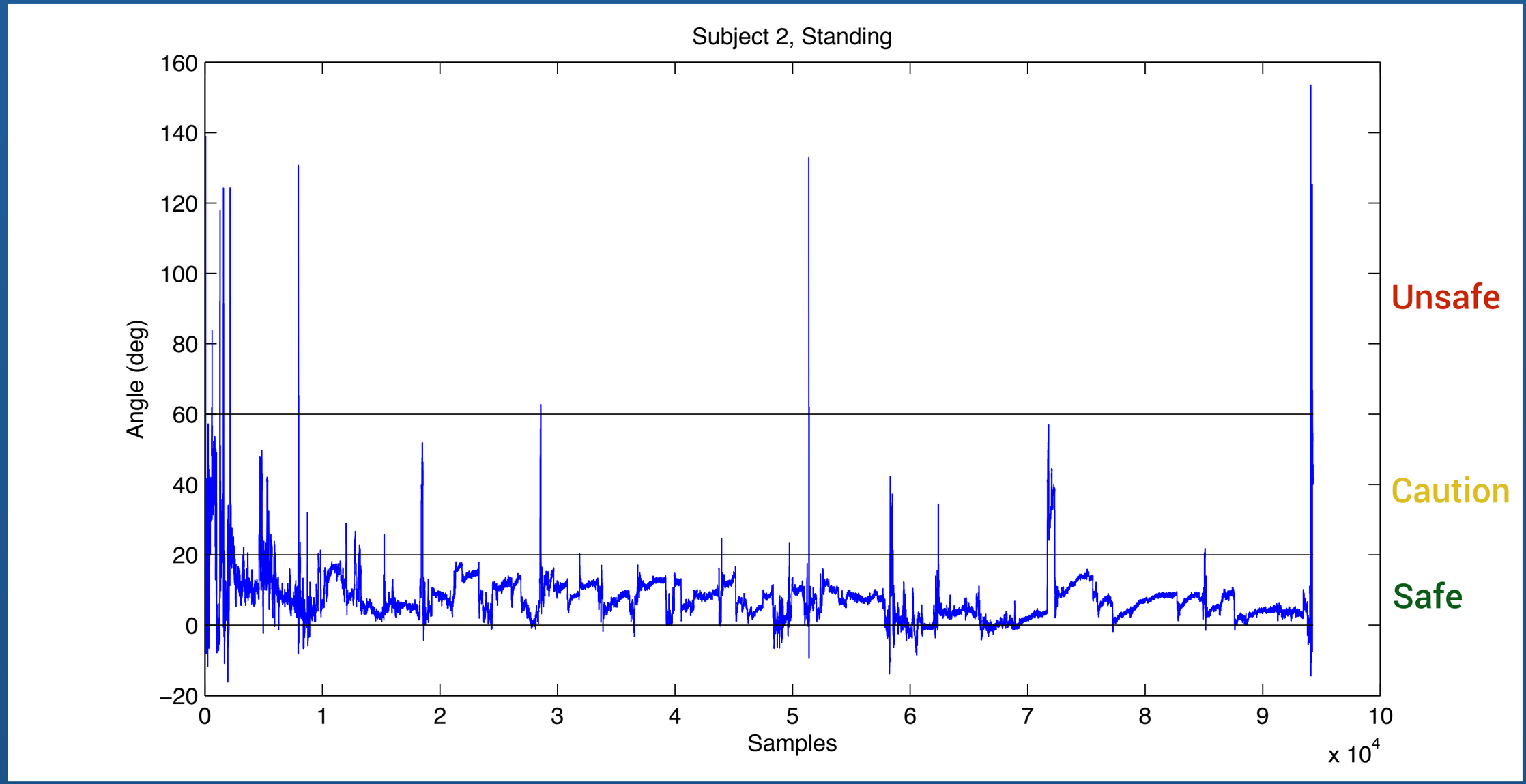


FIGURE 1.10
prEN 1005-4 diagrammatic model of the health risks associated with postures and movements (CEN 2003a).

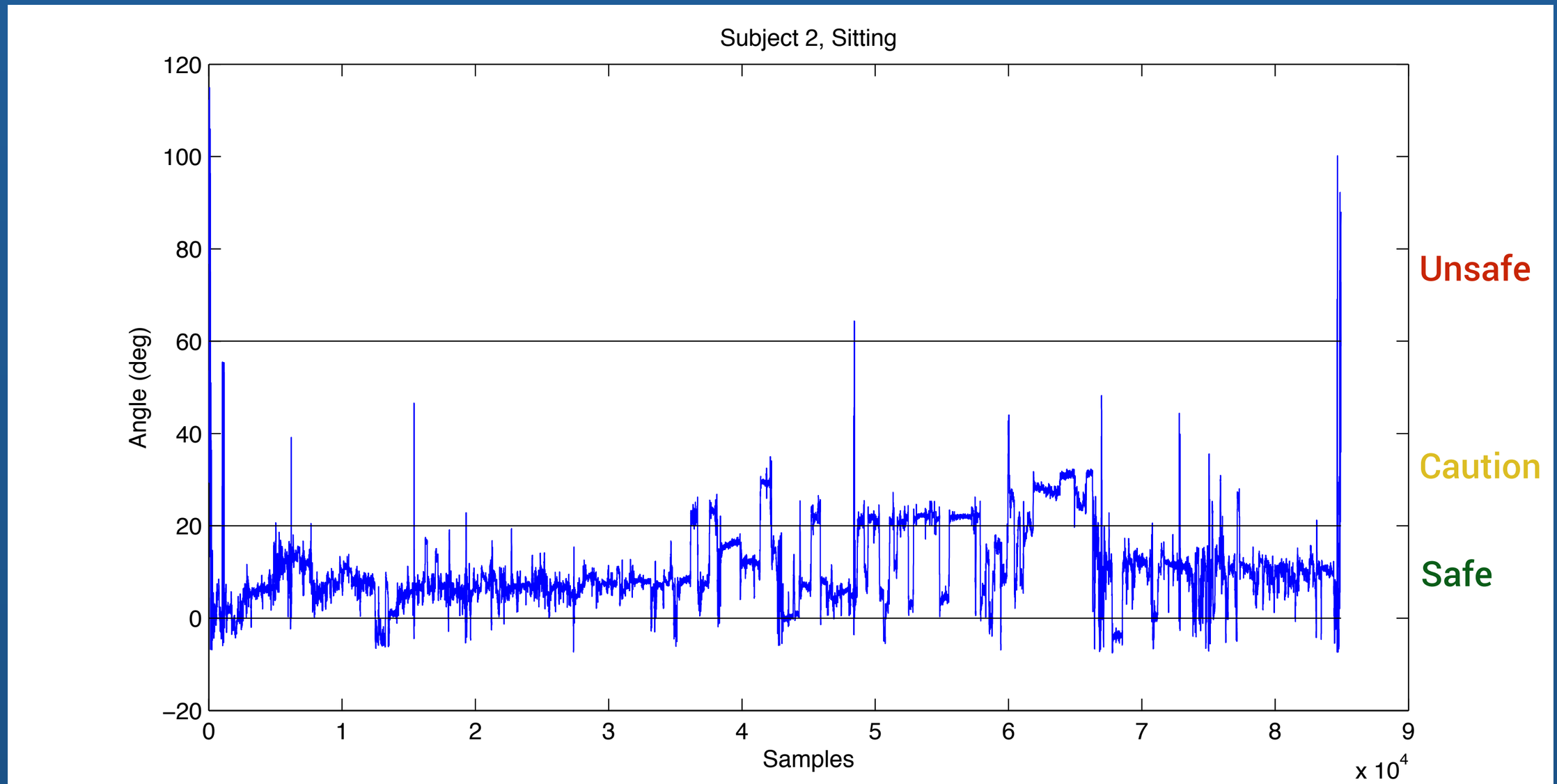
Table 11: Guidelines on static postures (mainly based on ISO/DIS 11226, 1999): *low back*

trunk inclination			
<0°	0–20°	20–60°	>60°
yellow/red**	green	green/yellow/red*	yellow/red

Angle of inclination when standing



Angle of inclination when sitting



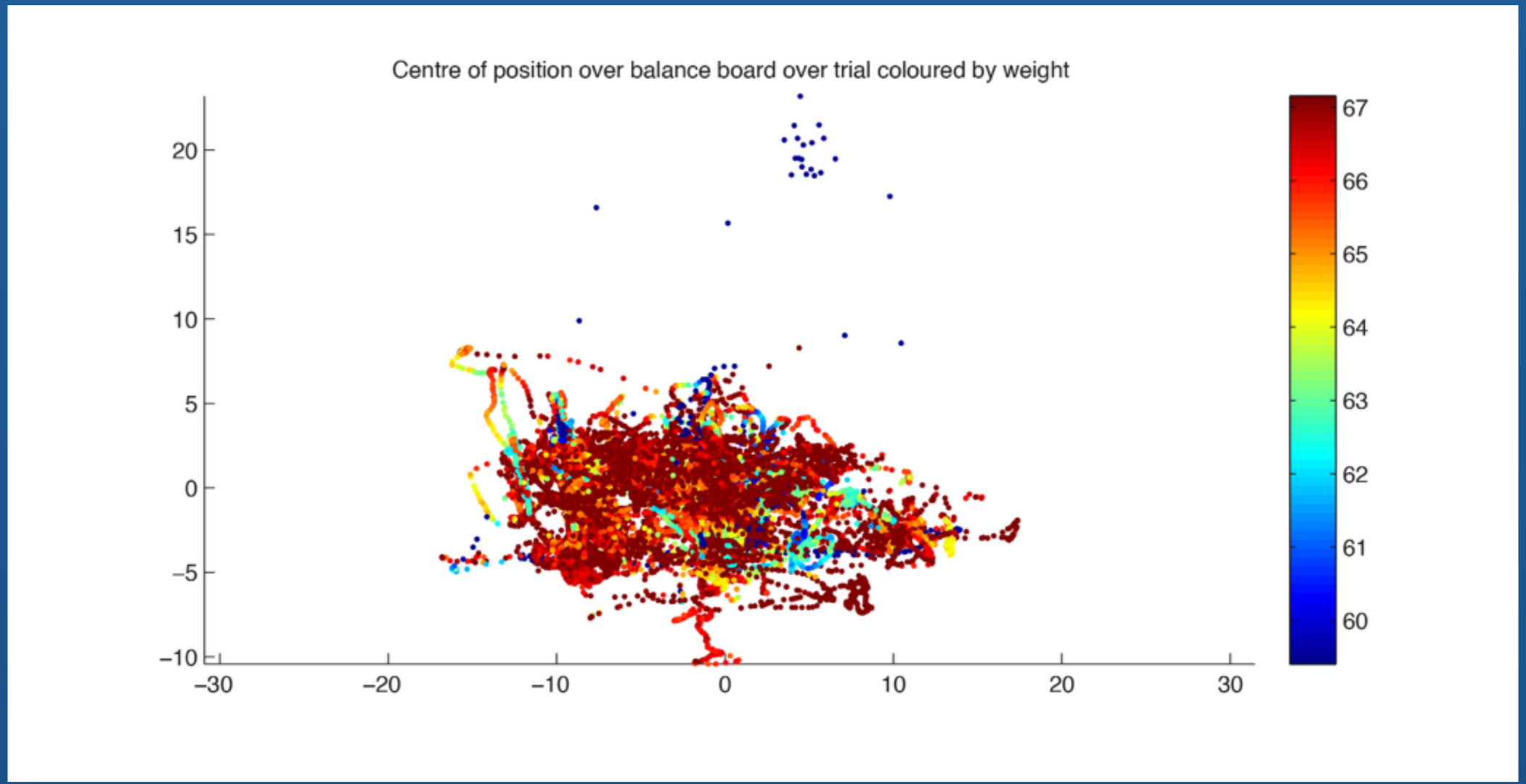
Angle of inclination: standing vs. sitting

95.5%	73.3%
Standing	Sitting

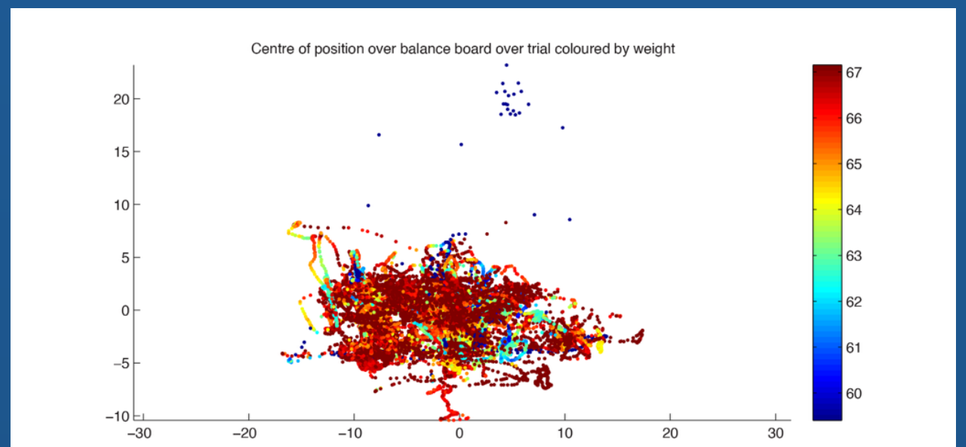
Percentage of time within “safe” back angle posture

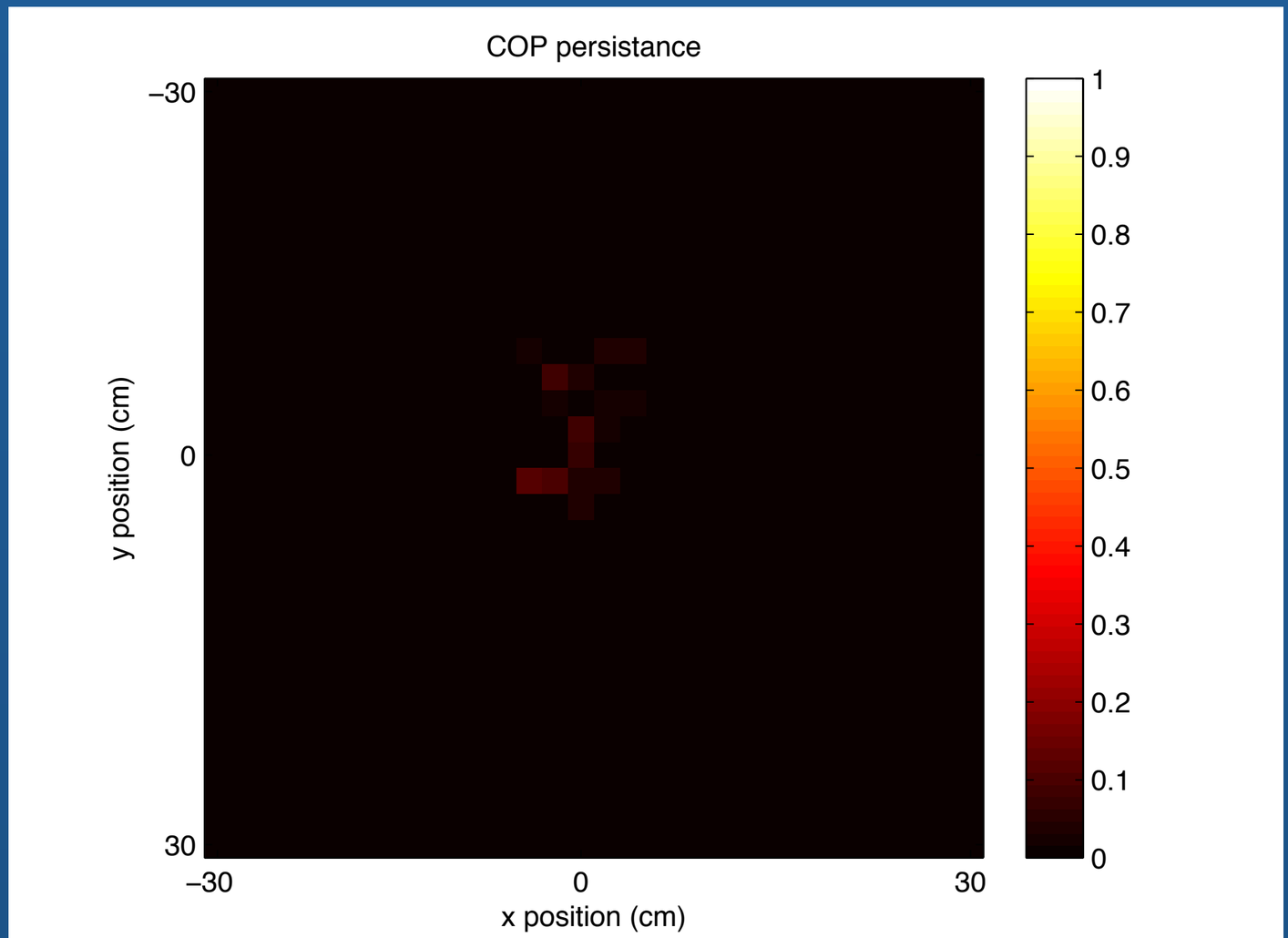
- Fatigue, if any, does not result in poor back posture when standing
- Sitting workstations induce poor posture more frequently

Results: Standing centre of position over time

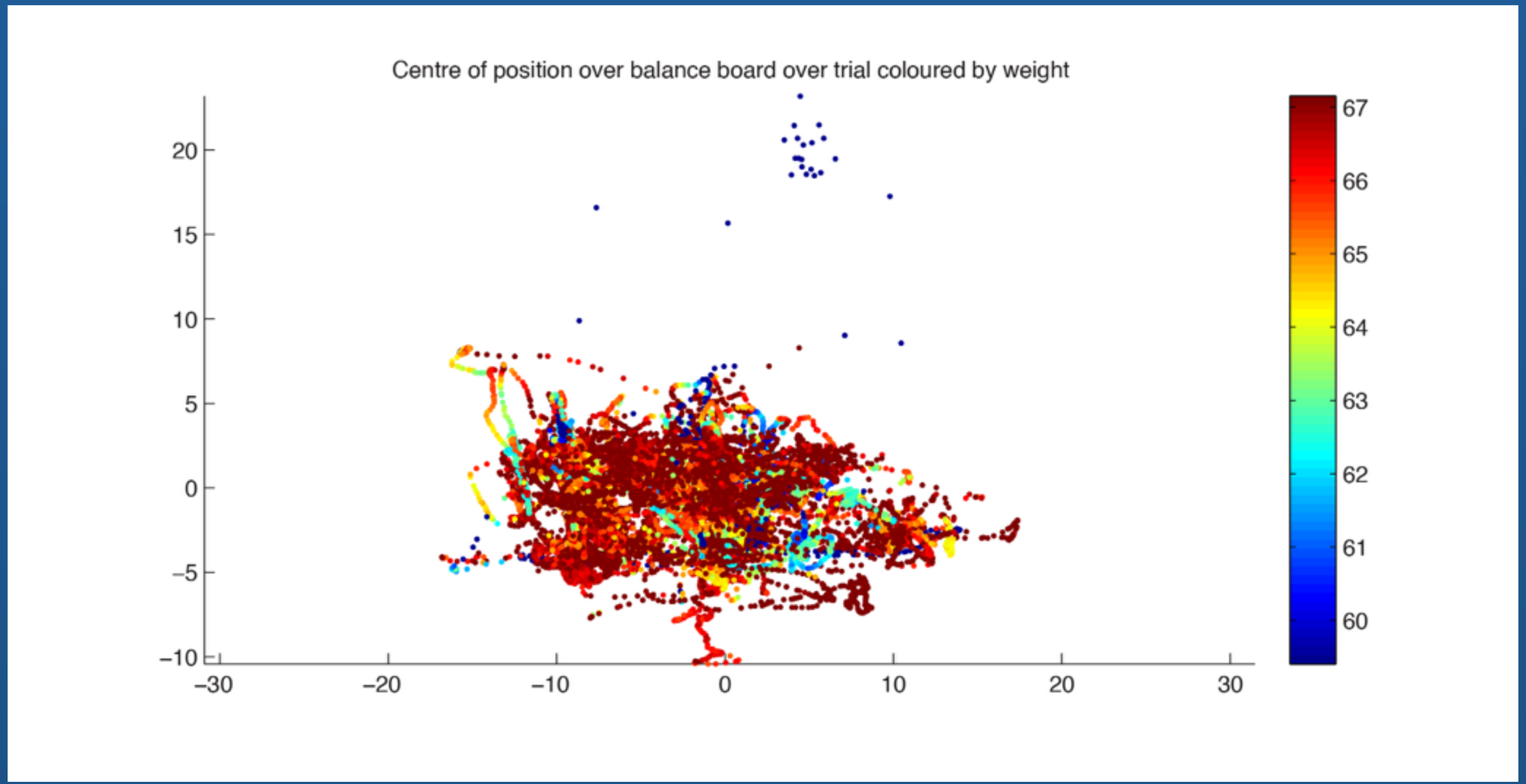


Results: Standing centre of position over time

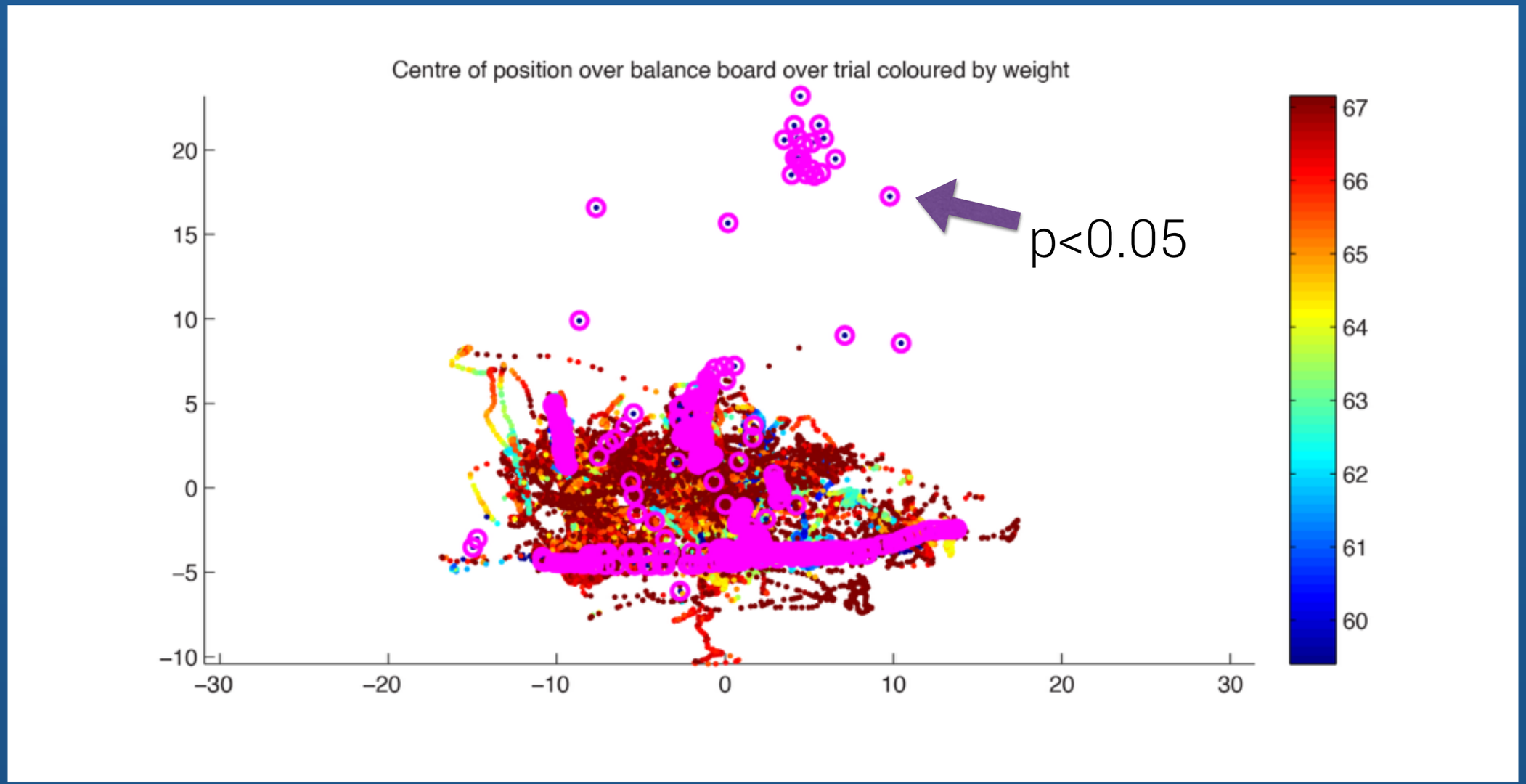




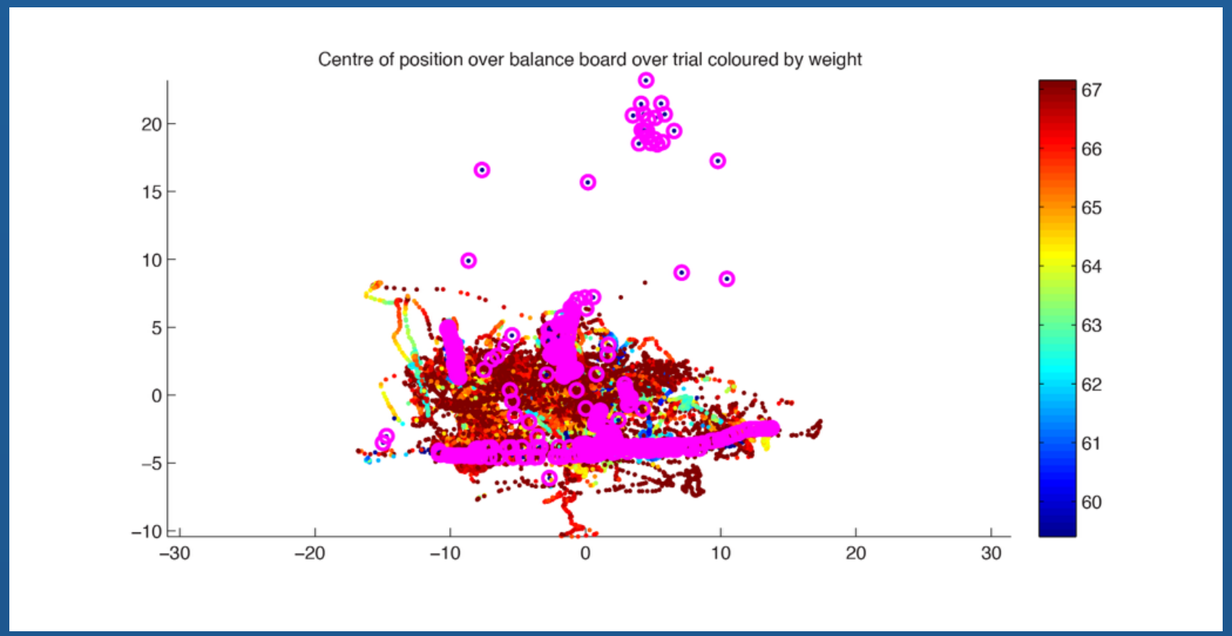
Results: Standing centre of position over time



Results: Standing centre of position over time



Results: Standing centre of position over time

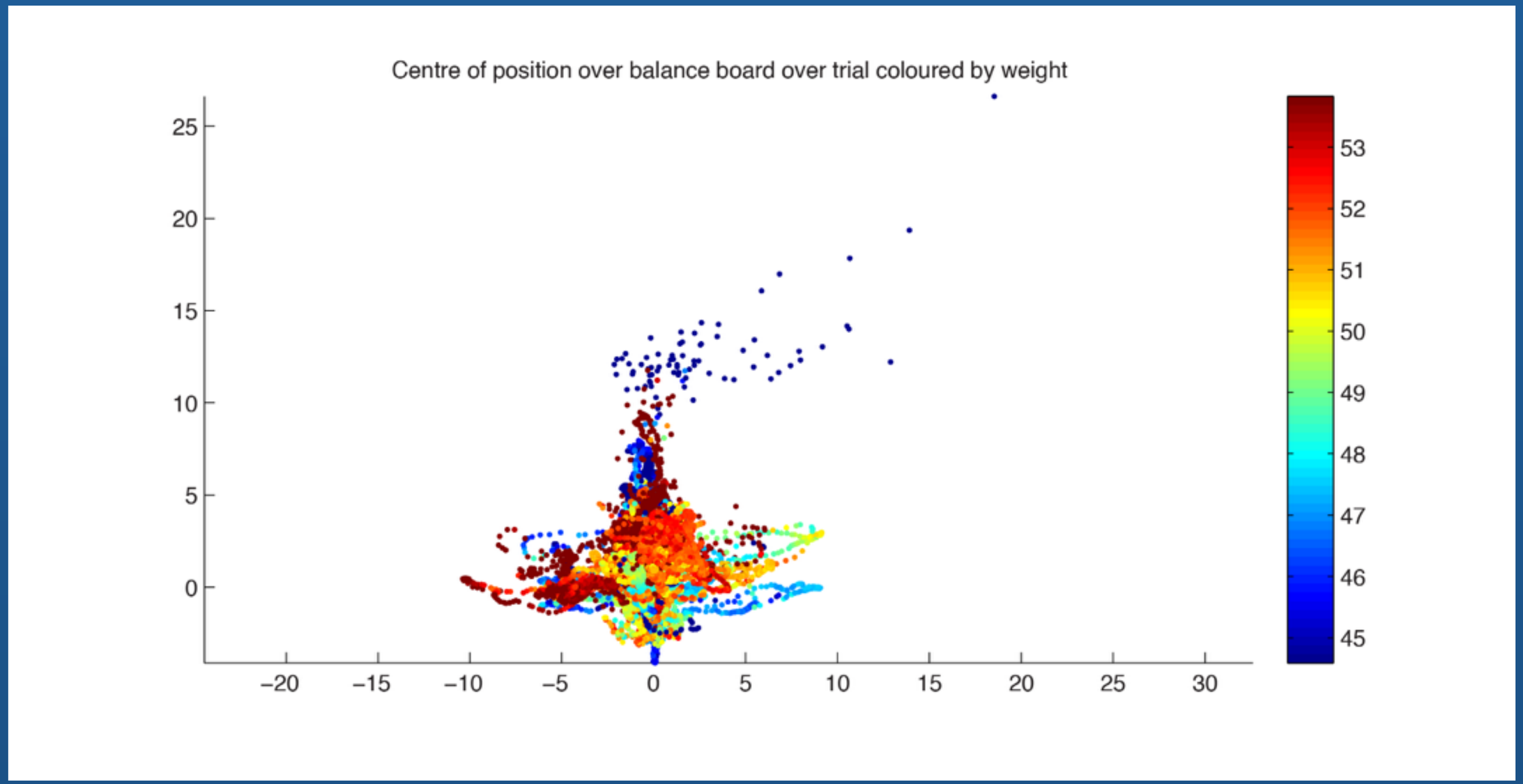


7 kg range in weight measurements

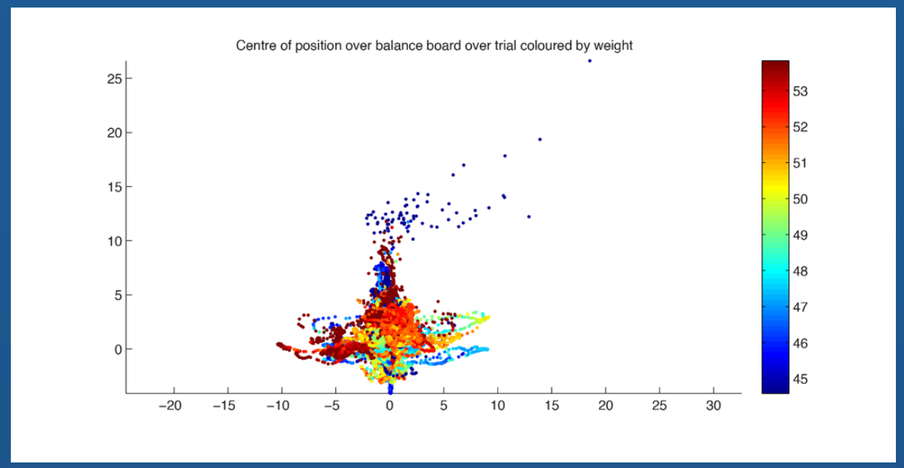
Suggests subject leaned on, and transferred weight to desk surface during experiment for stability or comfort.

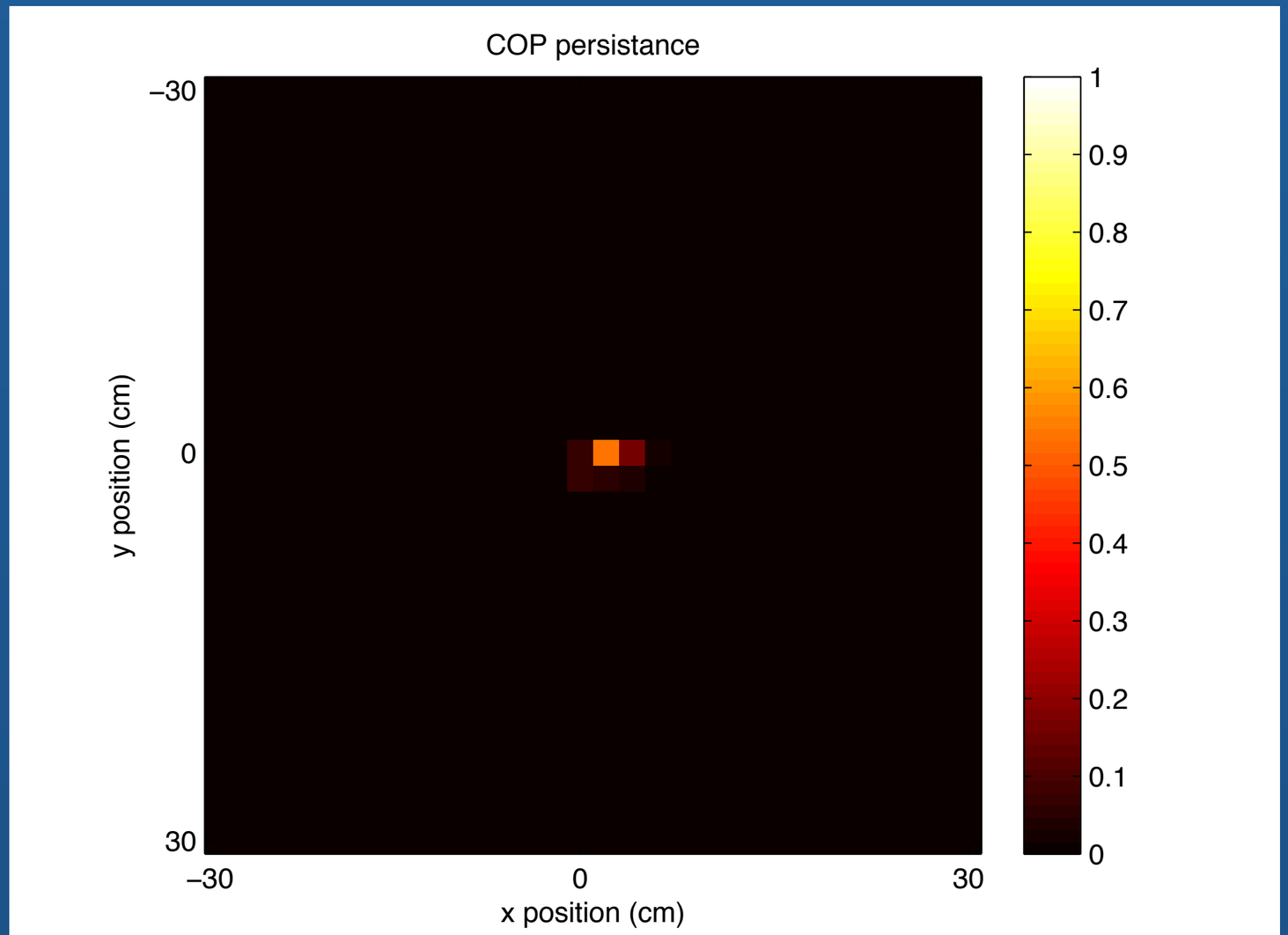
No detriment to back angle.

Results: Sitting centre of position over time

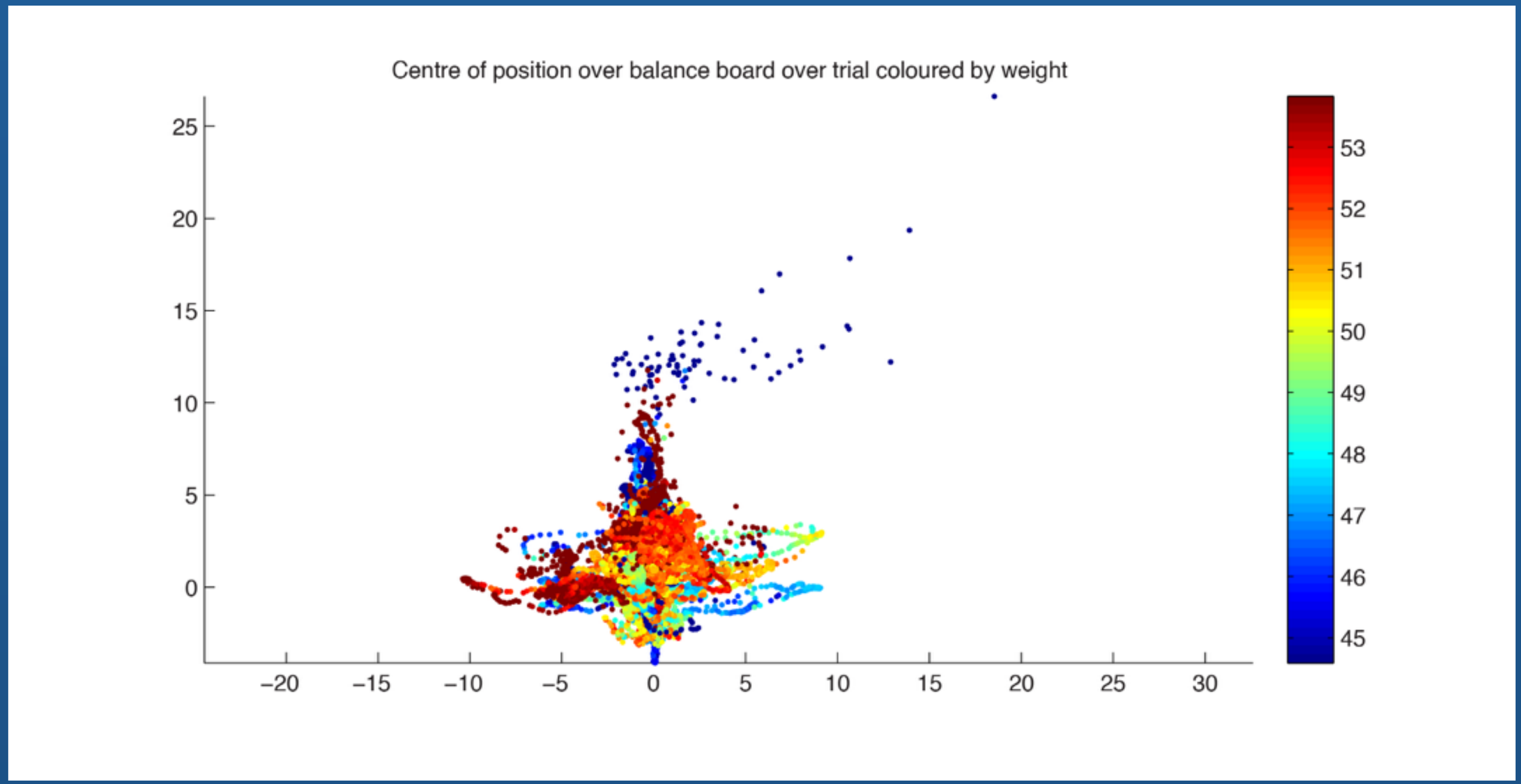


Results: Sitting centre of position over time

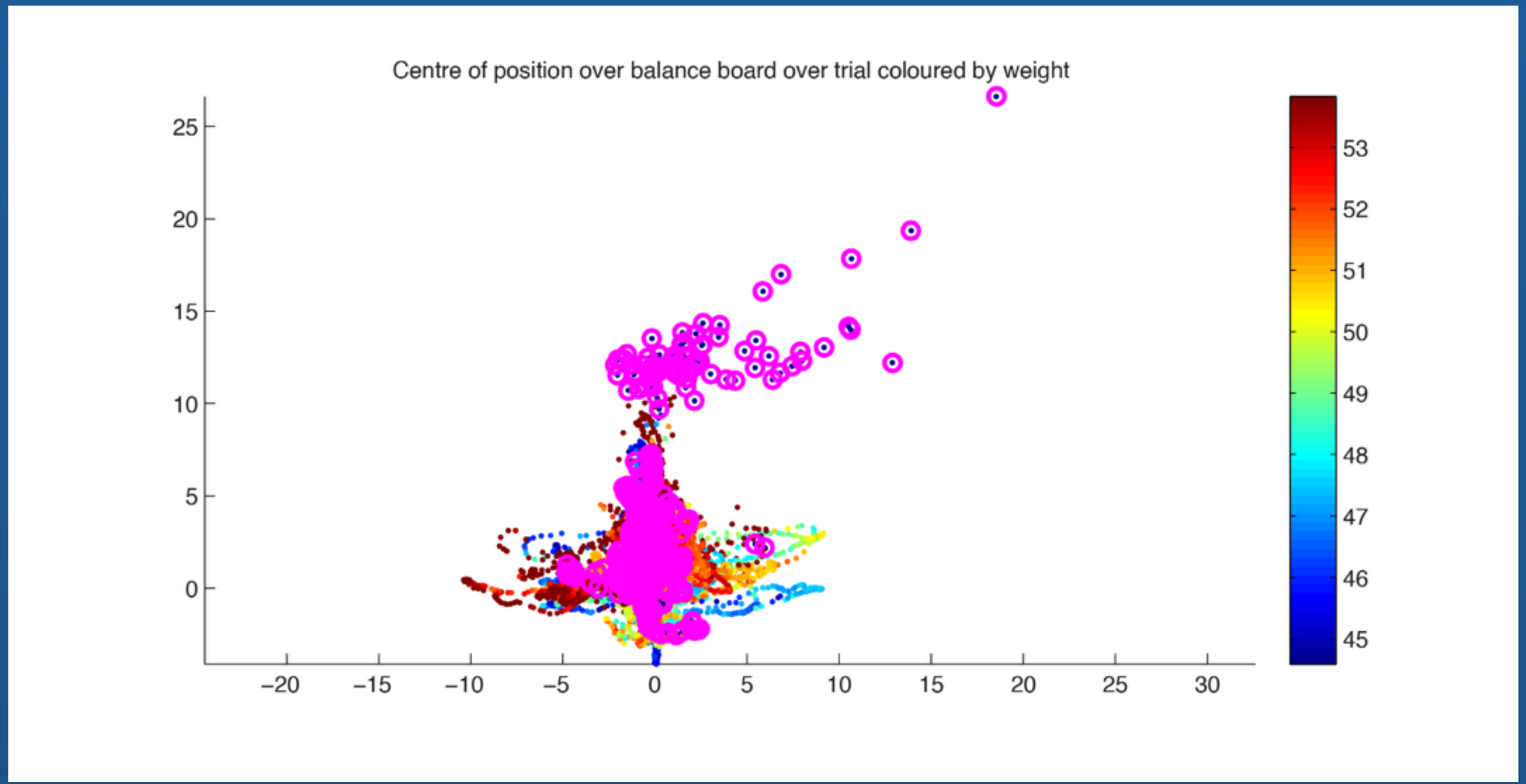




Results: Sitting centre of position over time



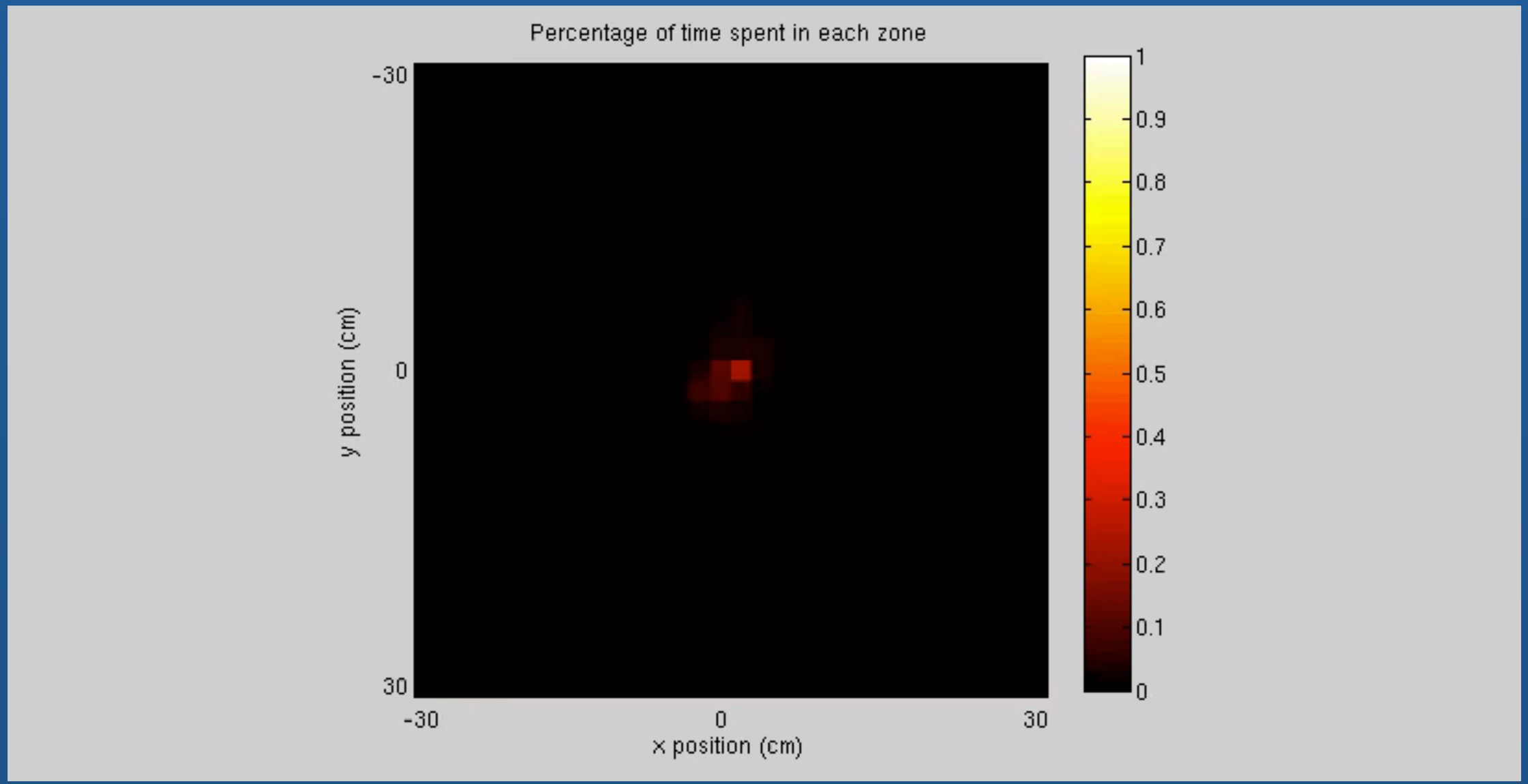
Results: Sitting centre of position over time



Posture remains stable

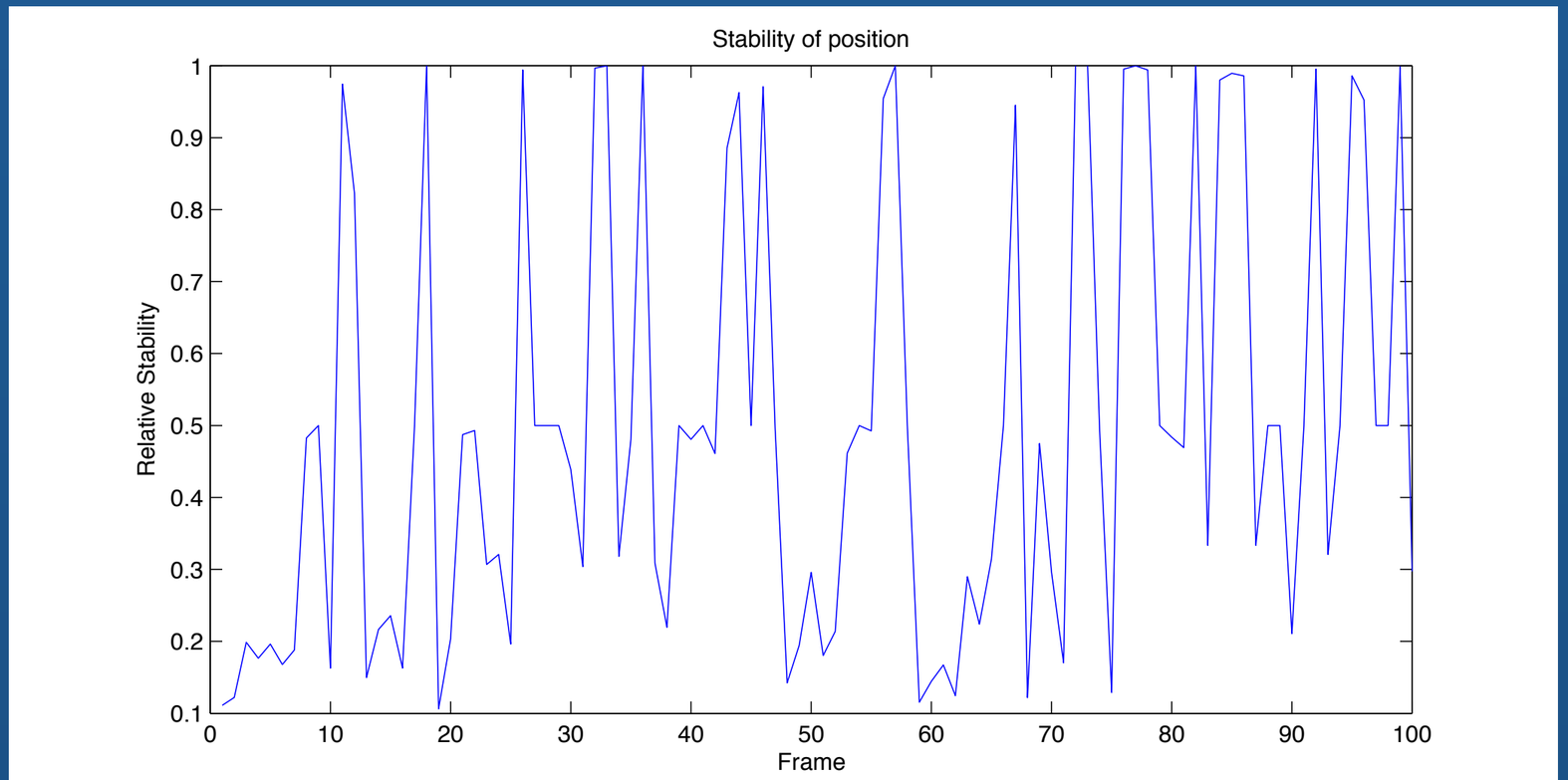
- Any potential increase in fatigue induced by long durations of standing did not seem to influence posture over time
- Centre of position, upper back inclination not significantly different between 0-15 min and 45-60 min.

Results: Centre of position over time



Results: Measure of stability

- Metric to indicate the shift of centre of position over the time
- “Dispersity” of COP in each frame



Excessive motion a marker for discomfort

- Excessive shifting (motion) while standing in a static posture is an indicator of discomfort when standing

  D. E. Gregory and J. P. Callaghan, “Prolonged standing as a precursor for the development of low back discomfort: an investigation of possible mechanisms.,” Gait Posture, vol. 28, no. 1, pp. 86–92, Jul. 2008.

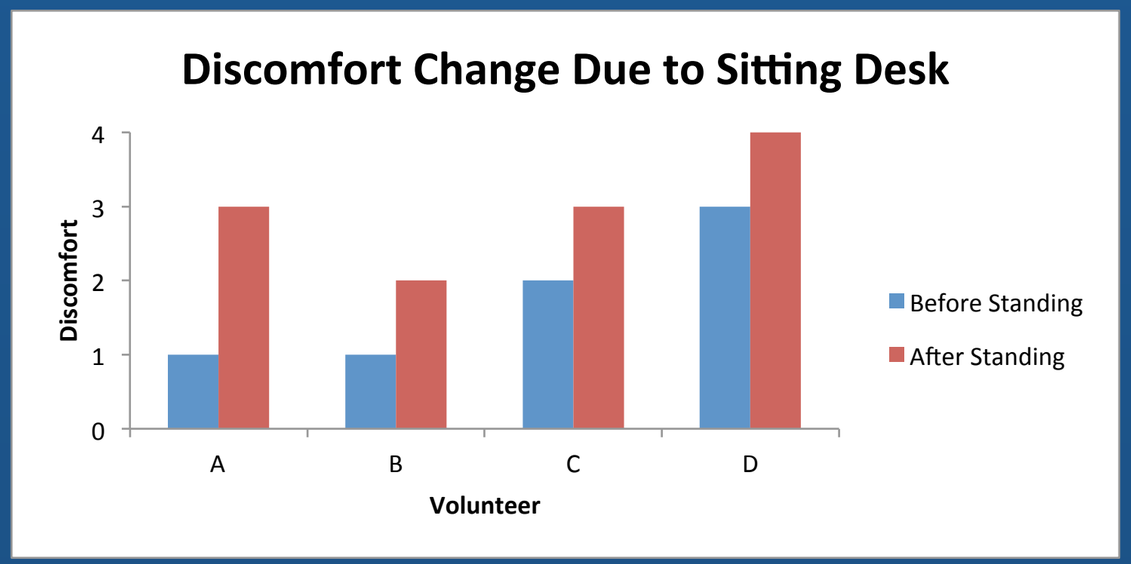
- This is also observed in our study
  - High shifting => Self-reported discomfort
- No increase in shifting when using standing desks

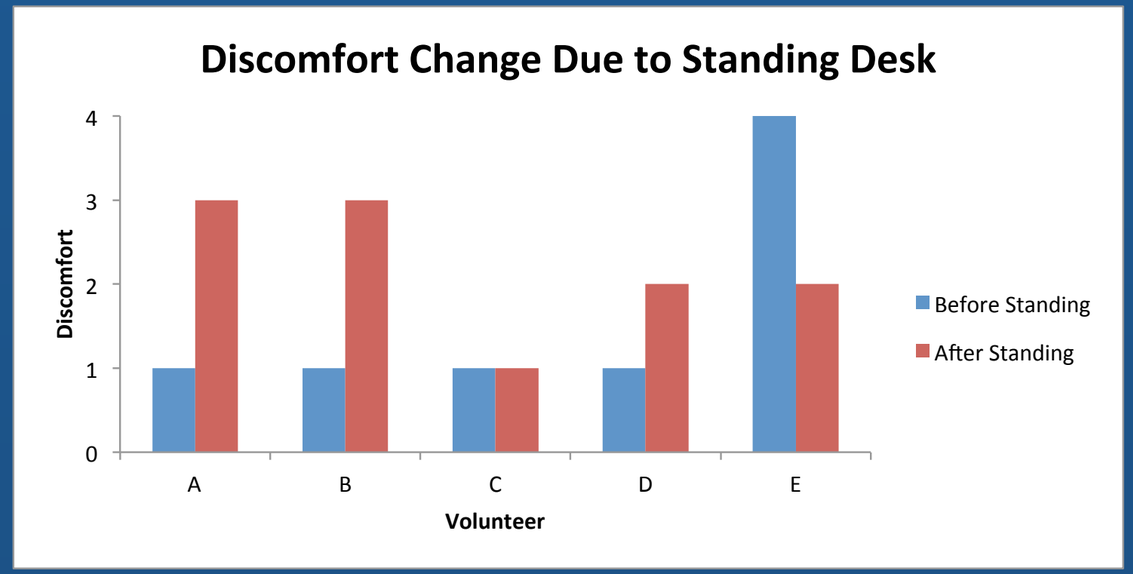
Motion when sitting

- Higher “dwell time” in a static COP in sitting measurements
- No prior study can be found relating shifting to sitting ergonomics

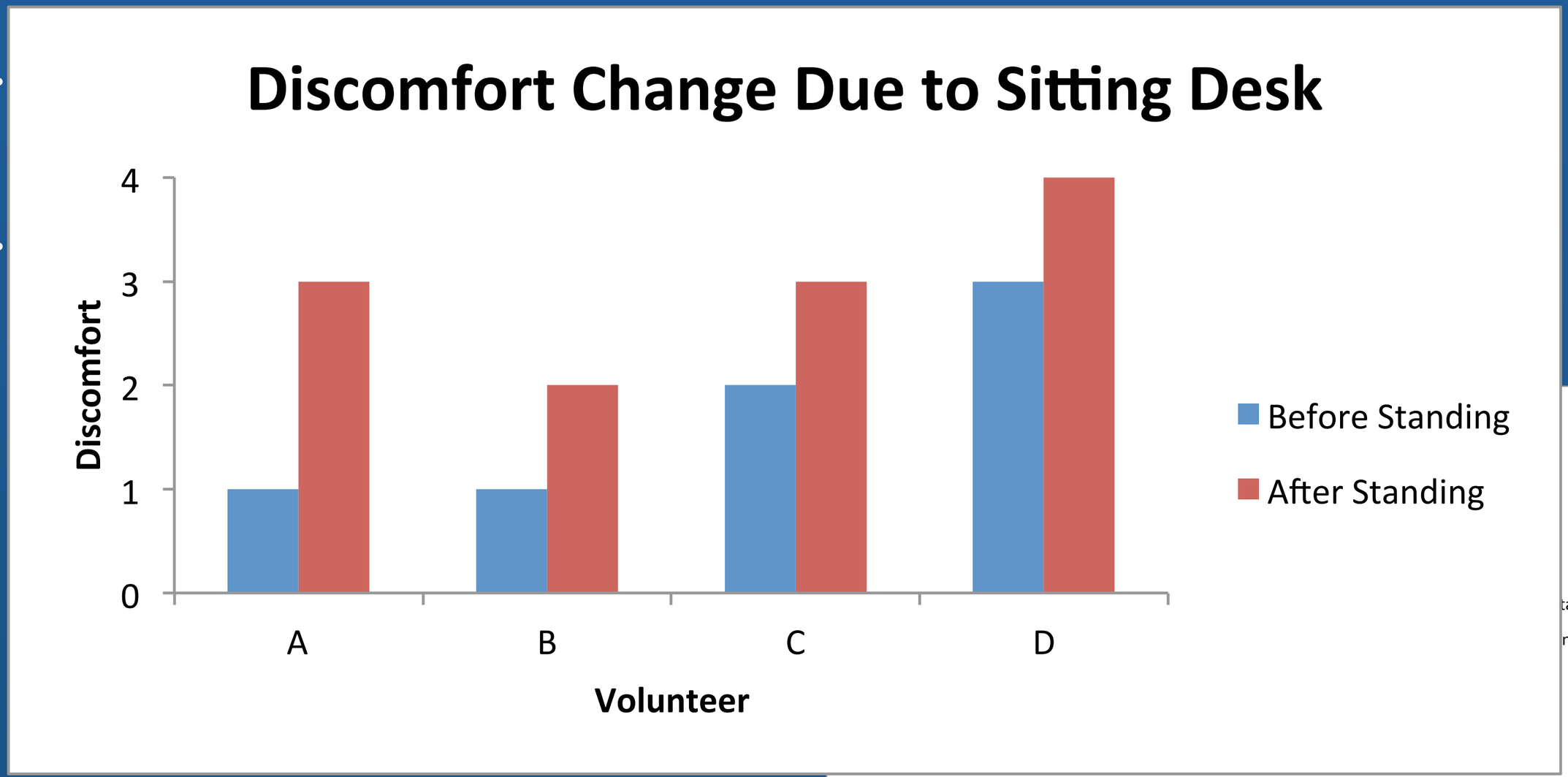
Sitting desks cause more discomfort

- Overall increase in discomfort after sitting and standing experiments
- More variance in standing discomfort

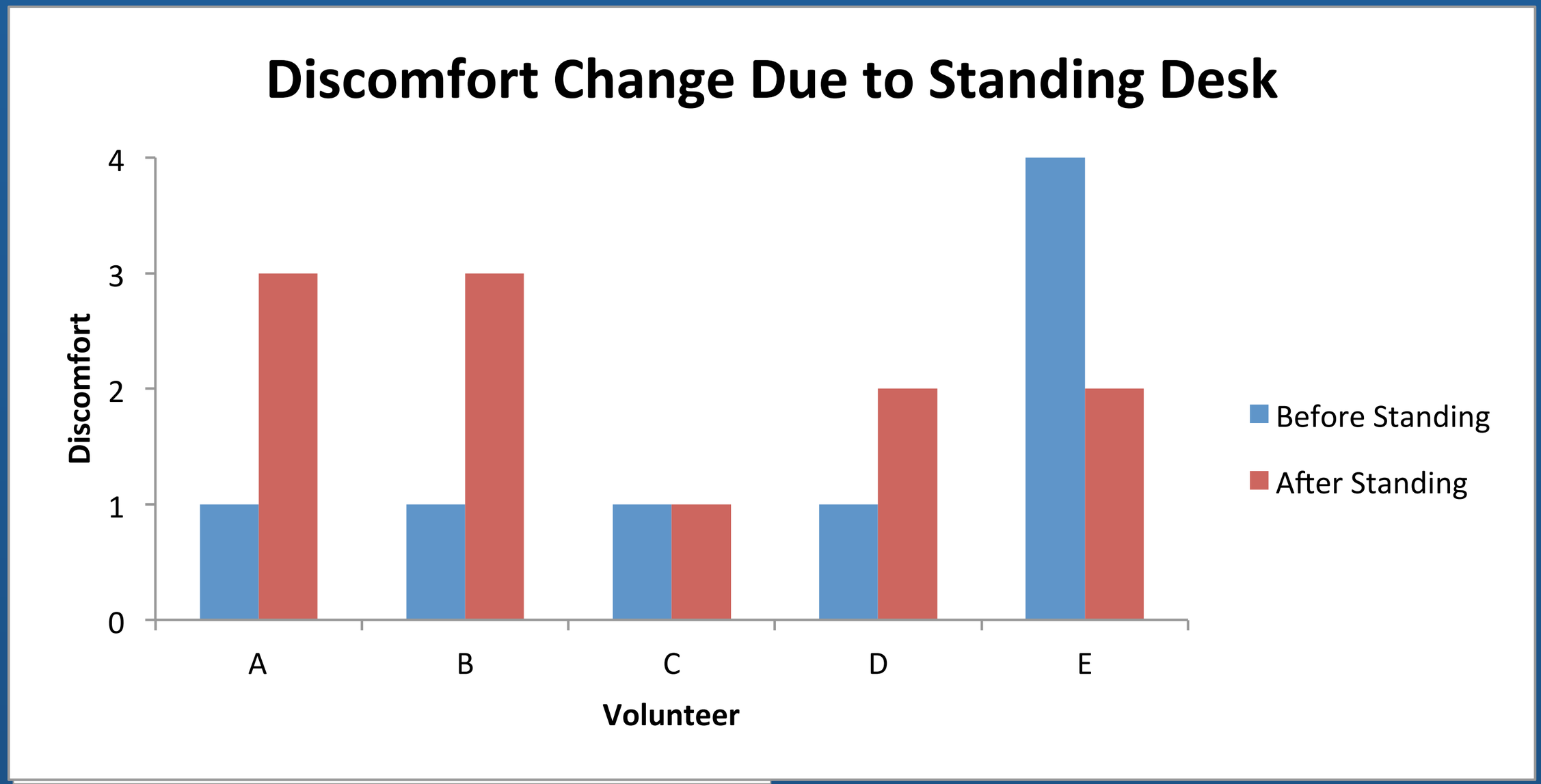




Sitting desks cause more discomfort



Sitting desks cause more discomfort



Reported regions of pain

Top three reported regions with perceived pain after experiment:

- Standing:
  - Feet, Legs, Lower Back
- Sitting:
  - Buttocks, Neck, Shoulders

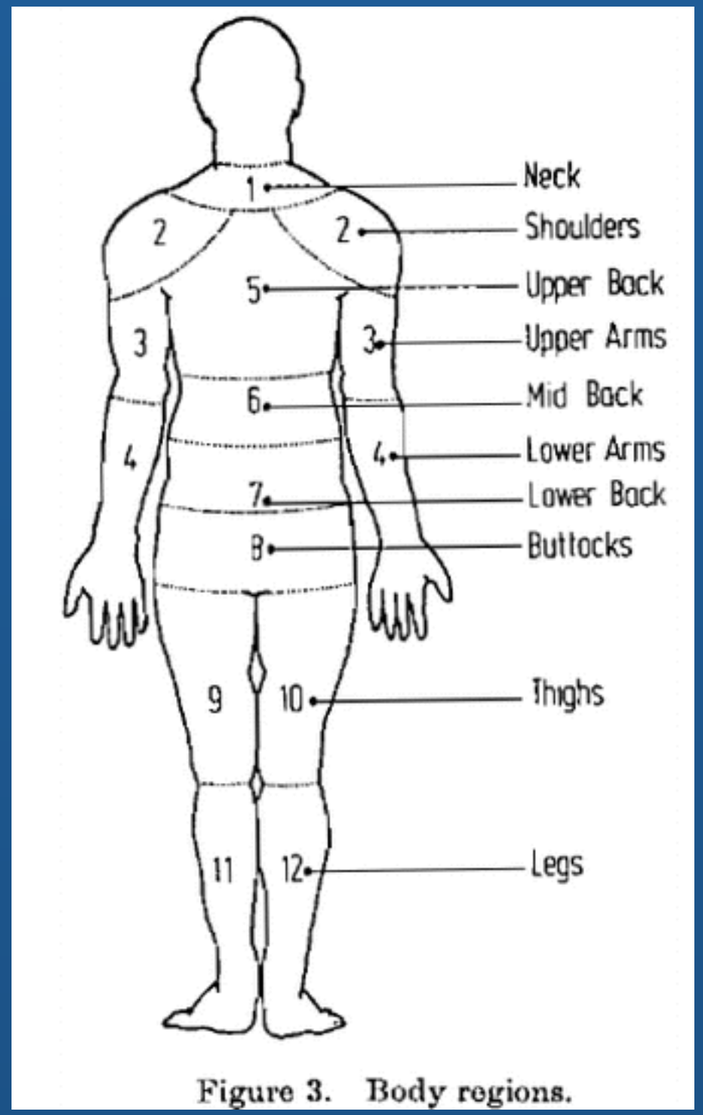
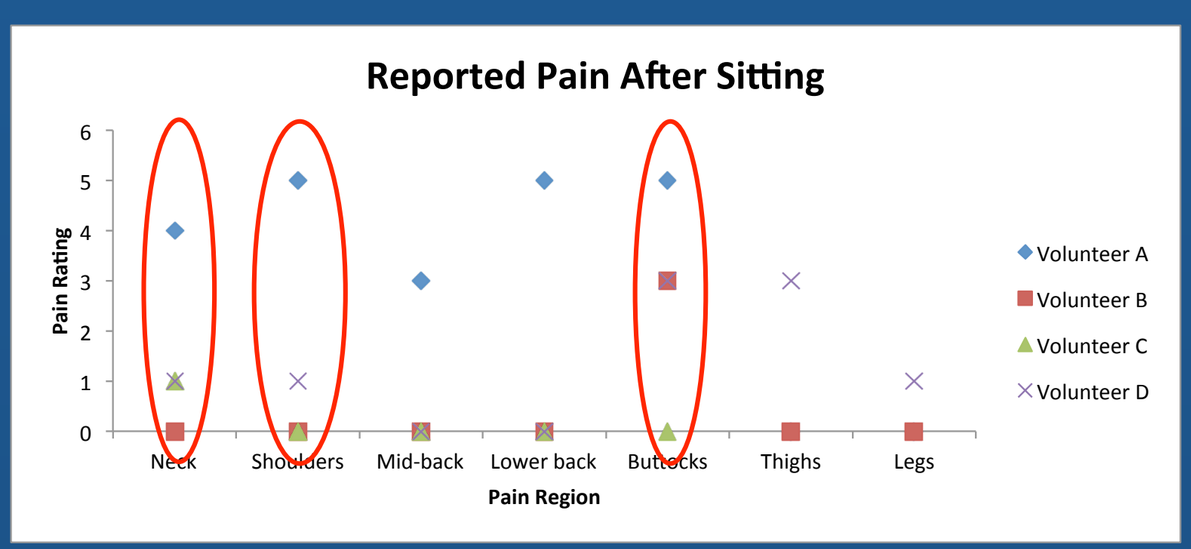
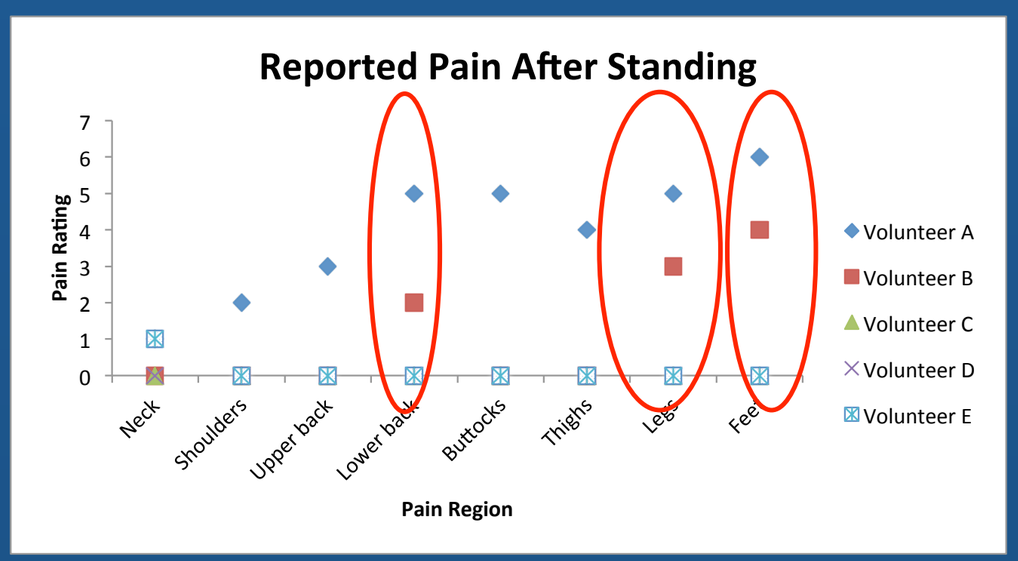


Figure 3. Body regions.

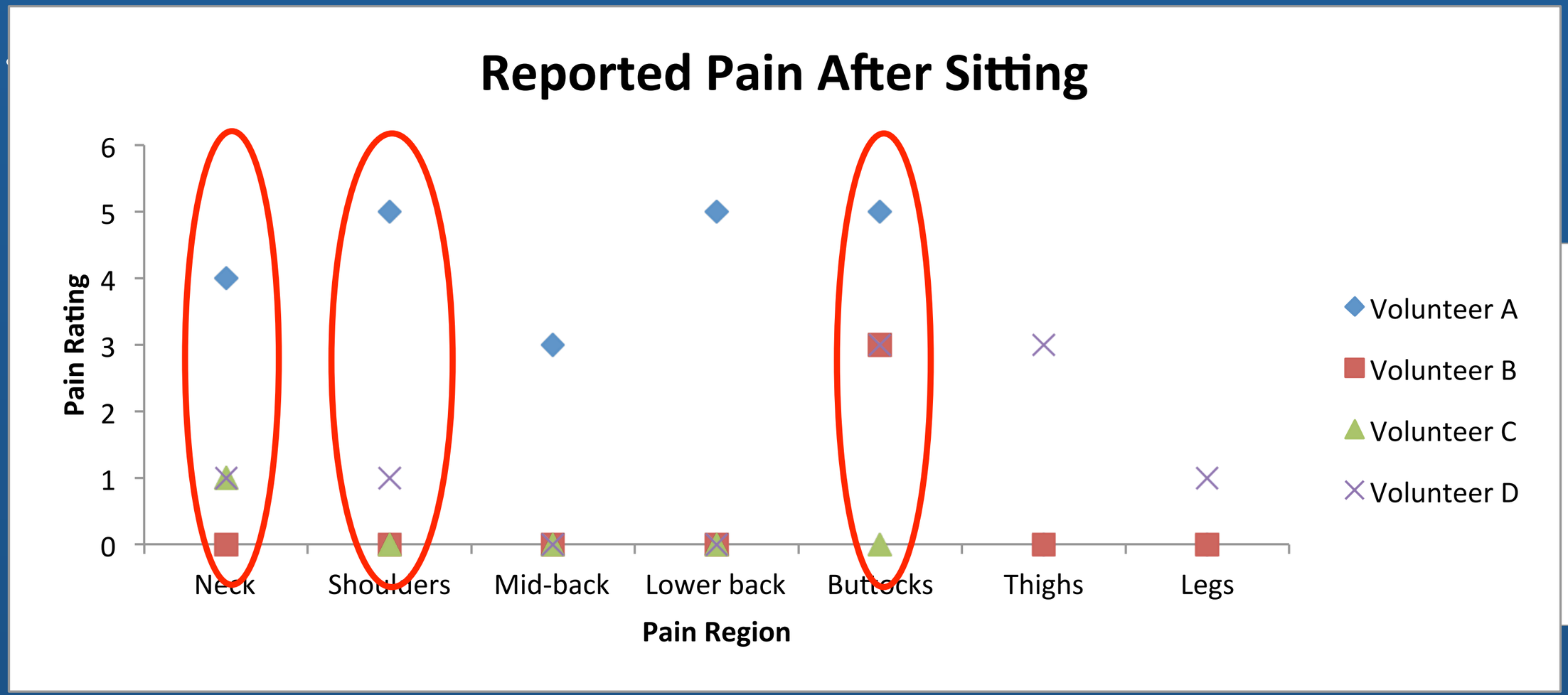
Reported regions of pain

- Average total pain rating higher in standing tests

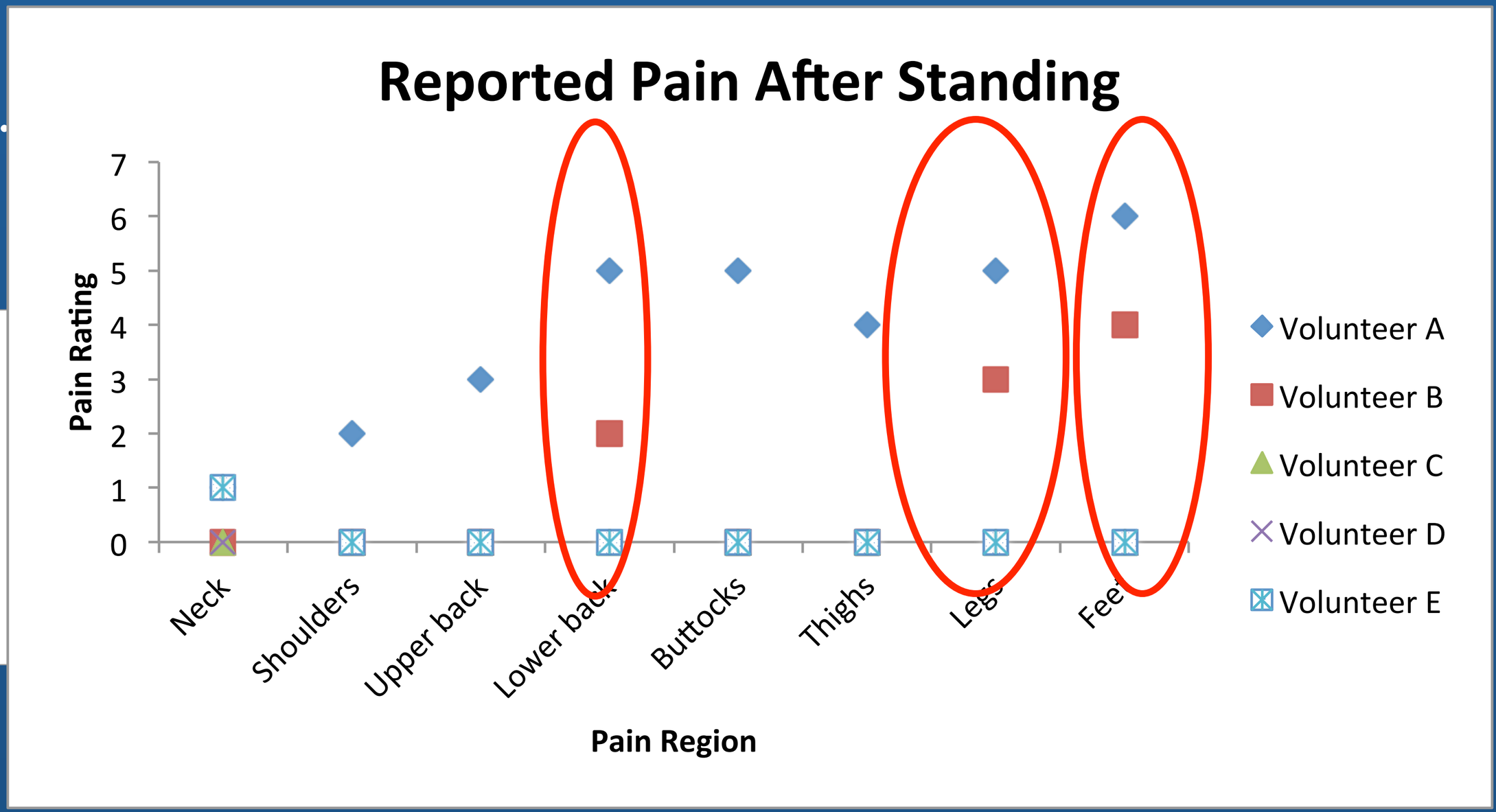




Reported regions of pain

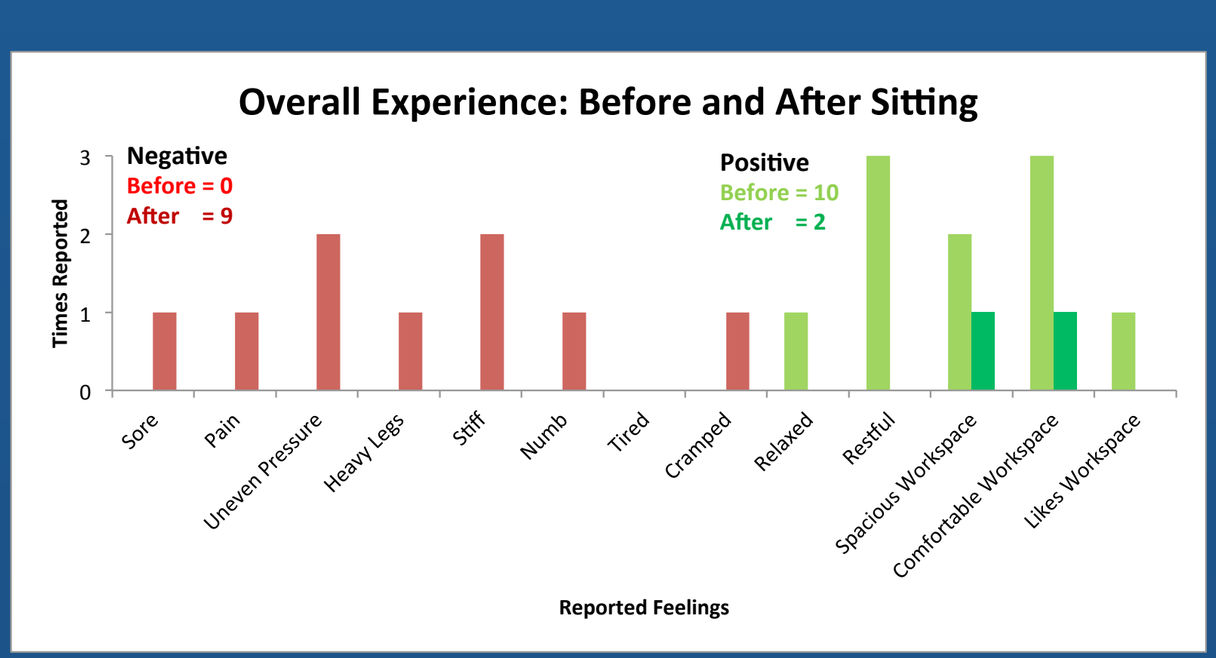


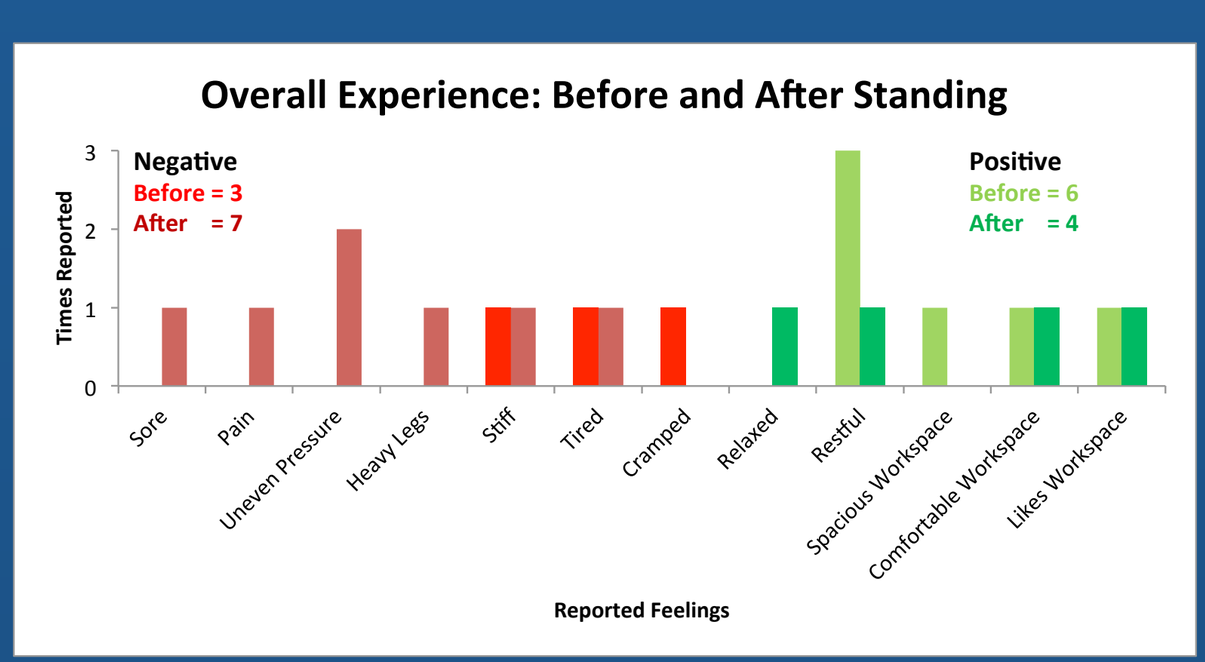
Reported regions of pain



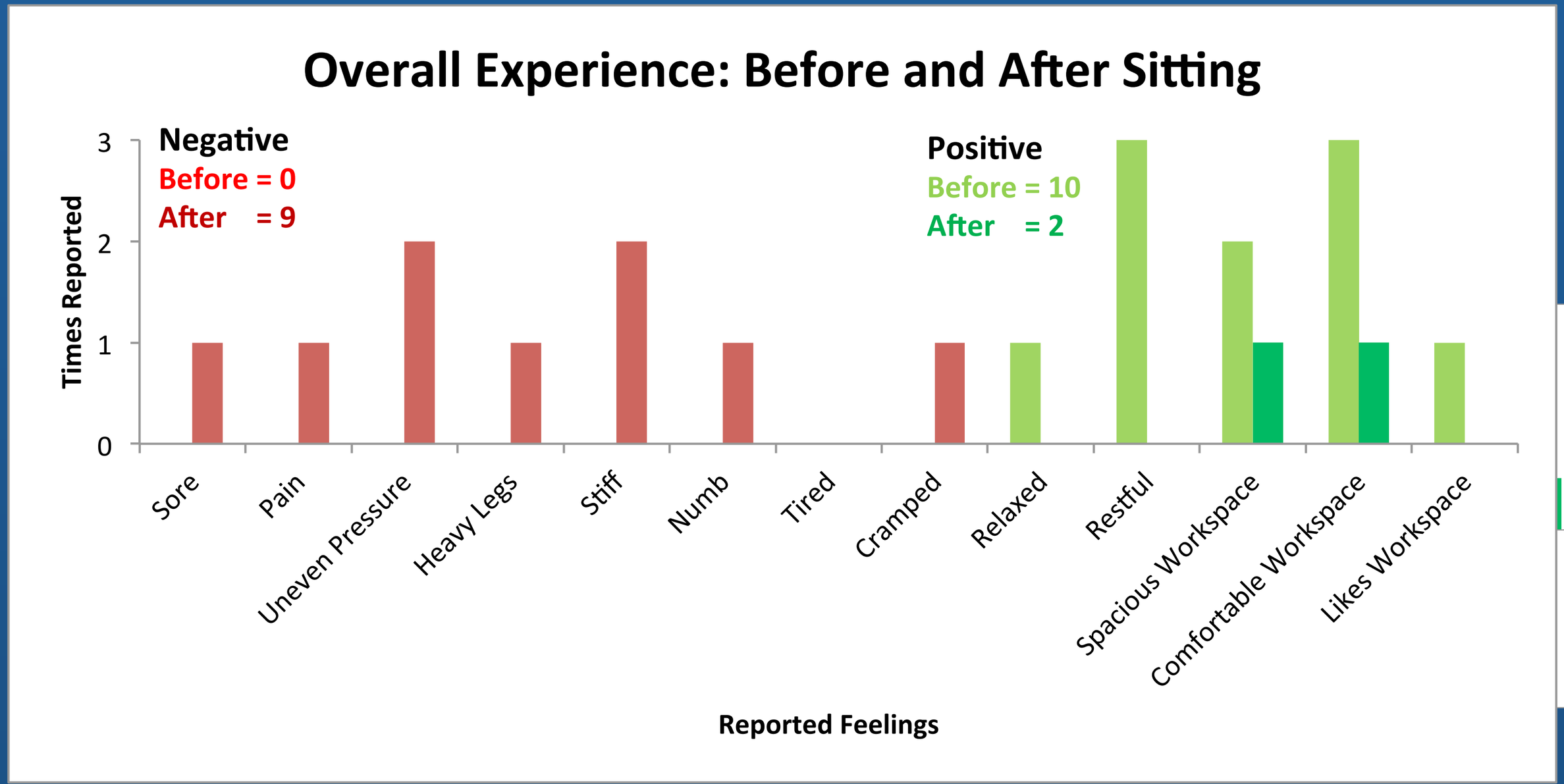
Overall reported experience

- Total overall experience indicates a more negative experience at a sitting workstation

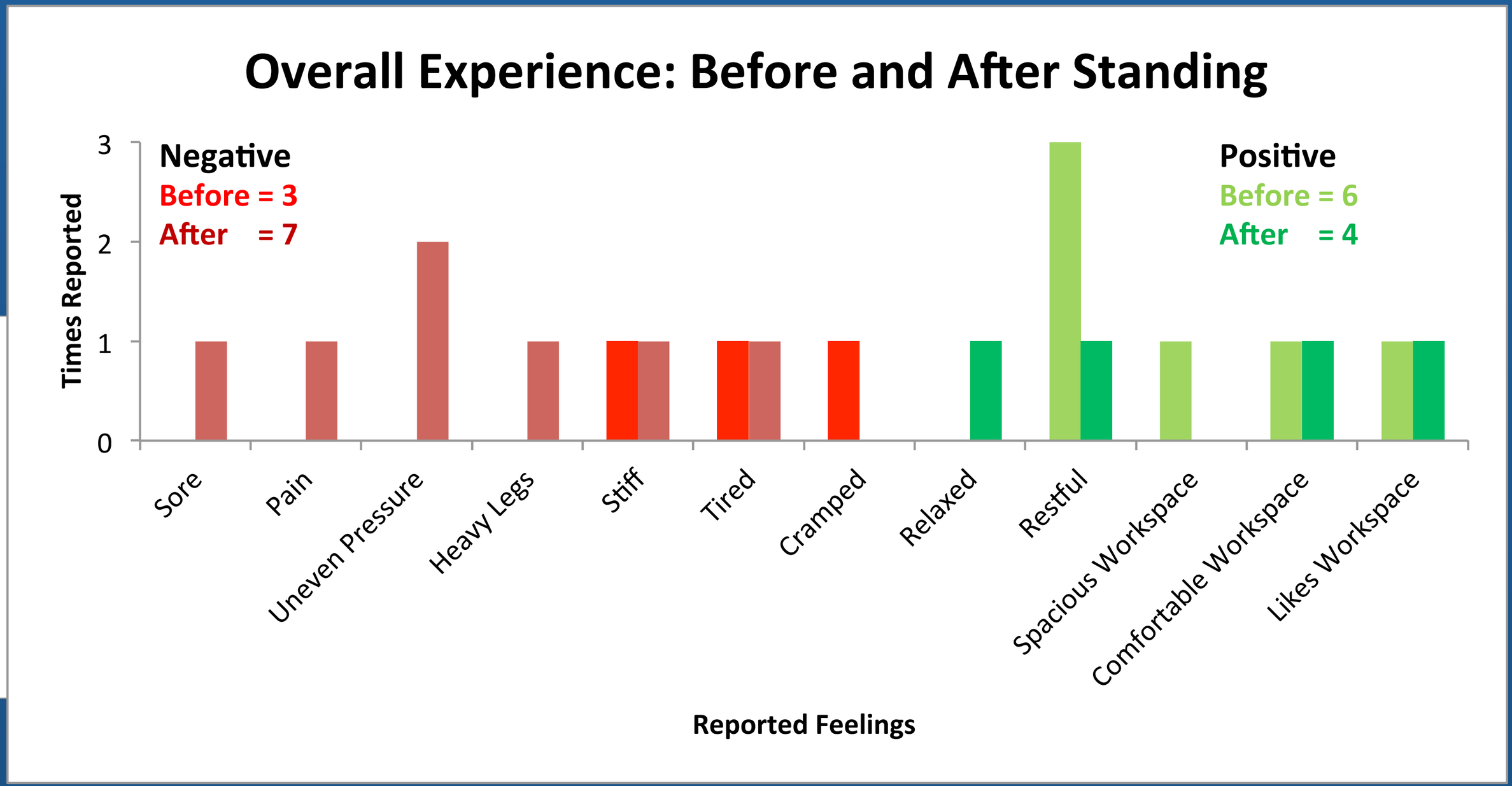




Overall reported experience



Overall reported experience



No evidence of ergonomic risk with standing desk

- No evidence to indicate any long-term ergonomic risk factors associated with the use of standing desks
  - Lower back angle of inclination within safe limits
  - Consistent COP with low shifting

Increased fatigue not associated with bad posture

- Any increased fatigue from prolonged standing did not result in discernable poor posture

Standing desks have an adaptation curve

- It takes time to become accustomed to a standing desk
  - Participants who use standing desk outside of study more comfortable with standing compared to sitting
  - Self-reporting for sitting desk users do not show comfort difference

Standing desks may not be for everyone

- Does not account for a wider range of physiological and pathological conditions
- One participant had flat feet:
  - constant motion on balance board
  - poor posture
  - constant discomfort

Limitations and future directions

- Sensitivity and suitability of instruments
  - Employed off-the-shelf consumer sensors
  - Application-specific sensors for future studies
- Measure additional spine and joint parameters in addition to truck inclination
- Self-reported pain subject to bias
- Future use of more ergonomic standing/sitting surface

Preliminary human factors study of standing desk ergonomics show no evidence of chronic risk factors associated with the use of standing workstations.

References

- [1] World Health Organization. (2010). Global recommendations on physical activity for health.
- [2] C. Mathers et al. (2009). Global health risks: Mortality and burden of disease attributable to selected major risks.
- [3] M. Saidj et al. (2013). Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study.
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- [5] D. E. Gregory and J. P. Callaghan, “Prolonged standing as a precursor for the development of low back discomfort: an investigation of possible mechanisms.,” Gait Posture, vol. 28, no. 1, pp. 86–92, Jul. 2008.

Thanks.

- Volunteer research subjects
- Neuromechanics Lab, Dept. of Integrative Physiology, University of Colorado at Boulder
- Hoda Maleki
- Prof. Craig Simmons

Thanks.

Questions?