Human posture: from fundamental postural control to workplace interventions

Julie N. Côté, PhD

Associate Professor, Department of Kinesiology and Physical Education, Associate Dean, research & graduate studies, Faculty of Education, McGill University, Montreal, Canada

Director, Occupational Biomechanics and Ergonomics Lab (OBEL), Laval, Canada (part of the Center for Interdisciplinary Research in Rehabilitation of Greater Montreal, Canada)

julie.cote2@mcgill.ca

ResearchGate: [https://www.researchgate.net/profile/Julie_Cote](https://www.researchgate.net/profile/Julie_Cote)
SOME DEFINITIONS

• **Postural control:**
  – the act of maintaining, achieving or restoring a state of *balance* during any *posture* or activity

• **Balance:**
  – an even distribution of weight enabling someone or something to remain upright and steady (synonym of stability, steadiness, equilibrium)
BASE OF SUPPORT

• area within lines connecting outer perimeter of each point of support

• An important concept linked with stability
WHAT AFFECTS STABILITY?

- The **height of the center of gravity** above the base of support (lower = more stable)
- The **size of the base of support** (wider = more stable)
- The location of the **force of gravity vector** within the base of support (at the center = more stable)
- The **weight** of the object (heavy = more stable)

When the gravity line lies outside the base of support – the system is unstable

→ A is more stable than B
HOW IS BALANCE CONTROLLED?

Vestibular system (inner hear)
- Regulation of head position

Visual system (eye)
- Absolute positioning (reference to the environment, e.g., vertical position)

Somatosensory system (joints, skin)
- Orientation of segments relative to each other
CLOSED & OPEN LOOP

• The system can access both circuits to maintain balance
Quantifying stability of standing posture

1) by quantifying the stabilogram (2D COP trace)

Some typical stabilogram outcome measures:

- Sway area
- Ellipse height
- Ellipse width
- Average distance from mean COP
- RMS distance
- Total path length
- Average velocity
- Mean frequency
- ...!
Other ways to quantify postural stability

• From the requirement of maintaining the gravity line within the base of support:
  
  – A perfectly stable posture = the body Center of Mass (COM) is perfectly aligned with the COP
  
  – Calculate the difference between COP position and vertical projection of COM (COP-COM)
  
  – More complicated: requires kinematic recording and computations

  • Techniques to estimate COM if no kinematic data available (e.g. double integration of the horizontal ground reaction forces, Lafond 2004)
COP-COM relationship during quiet standing

- The difference between the COP and COM (COP-COM) is proportional to the horizontal acceleration of the COM (= « balance error », in AP and ML)
The sheep and shepherd

1. In theories of postural control, the goal is for the shepherd (= COP) to continuously control the position of the sheep (= COM).

2. The COP moves to react to movements of the COM.
   - COP movements always occur after COM movements, but they should closely follow them.

3. Some conceptual problems with this:
   - It seems that indeed, the COP is the control variable (Ferry et al. 2004).
   - But how does the system detect, compute where its COM is?
   - ...
Rambling and trembling

- Rambling: migration of the resting position; gradual shifts, displacements of COP; control is thought to occur at the supraspinal level (Zatsiorsky & Duarte)
- Trembling: quick, online corrections that take rambling-related displacements into account; operated at the spinal reflex and local mechanical properties levels
How is this error controlled?

- Normal (easy), bipedal quiet standing:
  - Antero-posterior (AP) motion: controlled by ankle plantar-dorsiflexors (ankle strategy)
  - Medio-lateral (ML) motion: controlled by hips abd-adductors (hip strategy)

- To stabilize against perturbations: both ankles and hips can cooperate

- More challenging postures (e.g. tandem): roles can be reverse (ankle in-evertors help with ML control, hip flex-extensors help with AP control)

(Winter, 1995)
OVERALL POSTURAL CONTROL MODEL: INVERTED PENDULUM

- Original model of balance control: inverted pendulum
  - (body is one rigid segment oscillating about the ankles)

- Follow-up model: double-inverted pendulum
  - (accounts for motion at both ankles and hips)
It is possible to be in perfect equilibrium, perfectly still?

- No experimental demonstration that this is possible
- why?
  - Internal processes (e.g. breathing) make the body sway?
  - Some sway has a functional purpose? (online exploration of the physical environment)
  - it’s just not possible?
Effects of spine anatomy

• The spine has 4 curvatures (3 that affect standing posture)
  – There is a joint between most of the 33 vertebrae of the spine (sacral: it depends)
  – Lots of possible motion!
  – The standing posture is like balancing a 5kg weight (head) with a pliable stick
    • Requires fine control (erector spinae)
Effects of additional weight

- We originally said that more weight = increased stability but...
  - Reduced postural stability with extra loads in adults (Qu & Nussbaum) and children (Pau & Pau)
  - Reduced postural stability with obesity, return to normal values after weight loss ((Teasdale group)

- Extra weight requires a stronger push to disrupt equilibrium, but according to the inverted pendulum model, once it’s disrupted, a heavier body becomes unstable more quickly
  - Specific mechanisms not clear
Postural stability and fatigue

• Increased postural sway with fatigue (Paillard 2012)
  – Of ankle plantar-dorsiflexors (Vuillerme)
  – Of neck muscles (Schieppati)
  – Due to prolonged standing (Corbeil)
  – After a triathlon and a 5h exercise (Lepers)
  – After 4 days of hiking (Vieira)

– Could be due to fatigue-related changes
  • to the agonist muscles,
  • to other muscles involved in postural control,
  • To cardiovascular or respiratory effects
  • To overall changes affecting postural control processes
Clinical aspects of postural control

- Conditions with impaired balance:
  - Parkinson’s Disease
  - Multiple sclerosis
  - Stroke
  - Spinal cord injury
  - Musculoskeletal injury
  - Diabetes
  - ...

- Some clinical balance tests:
  - Romberg test
    - Increasingly challenging postures (e.g. eyes closed)
  - Timed up and go test
  - Berg balance test
    - Everyday life tests
    - Used frequently with stroke
  - Many others

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Coordinating posture and movement

- What happens if we add limb movements?
  - Suddenly the goal is not only to maintain upright posture
    - Although postural stability can still be maintained through the control of the COP (Ferry et al., 2004)
  - But combining posturography and upper limb kinematics provides results that suggest the creation of a posture-movement synergy
    - Stapley: arm-trunk synergy
    - Côté: arm-upper body in phase movements with fatigue
Coordinating posture and movement when posture is challenged

- Trivedi 2010: short latency perturbation responses focus on postural control, longer latency ones account for coordination between posture and movement.
- Fuller 2013: adaptations to postural perturbations and to arm muscle fatigue occur independently from each other.
- Cantu 2014: adaptations to added weight (postural challenge) and to arm muscle fatigue occur independently from each other.
- The system is built to be able to prioritize balance, but has ways to adapt to coordinate postural stability with limb movement production.
CONTROL OF SEATED POSTURE

• Typically easier to achieve balance
  – only half of the body to stabilize
  – Large base of support

• Depends on absence or presence of back rest
Measurements of seated postural stability

  - Validation of pressure mat to measure seated postural stability in healthy children
  - Experimental tasks: quiet sitting posture, seated reaching (AP, ML)
Results

- Pressure mat is valid and reliable, especially for reaching tasks (more than for quiet sitting)
  - Issue of spatial resolution
FROM THEORY TO (ERGONOMICS) PRACTICE: the work posture and associated health risks
Standing work

• Can a standing work posture cause health problems?
  – Working in a standing position may cause:
    – sore feet,
    – swollen legs,
    – varicose veins,
    – general muscular fatigue
    – low back pain
MEASUREMENTS OF THE EFFECTS OF PROLONGED QUIET STANDING

- Callaghan’s group (Waterloo)
  - People with low back pain (LBP) have elevated co-activation (measured by cross-correlations) of trunk flexors-extensors, and of bilateral gluteus muscles during quiet standing
  - Prospective link: workers who eventually develop LBP already show elevated co-activation before symptoms arise: an inherent cause of injury, predisposing factor?
  - Sign of stiff (rigid) back?
  - Can it be trained?
MEASUREMENTS OF THE EFFECTS OF PROLONGED STANDING WORK

• Antle PhD thesis:
  – Increased leg discomfort during 30min of standing work
    • Correlated with increased blood flow to the feet and increased ankle arterial blood pressure
    • Mechanism for standing leg discomfort is vascular
    • Ankle EMG amplitude decreases with time
    • A way to increase sway to help the blood return up?
  – Increased low back discomfort after 30min of standing work, but not correlated to vascular or muscular changes…
    • Low back pain likely multifactorial
SYMPTOMS ASSOCIATED WITH PROLONGED SITTING

• Low back pain  (Hedman and Fernie, 1997, Lord et al. , 1997).
  – Could be due to increased intradisc pressure, trunk muscle loading or lumbar stretch tissue  
    (Mork and Westgaard, 2009)

• Sciatica
  – Could be due to sitting time and posture
Advantages of working sitting

– Provides stability required in tasks with high visual and motor control demands
– Less energy consuming than standing
– Places less stress on the lower extremity joints
– Lowers hydrostatic pressure on the lower extremity circulation
Sitting (cont’d)

- Sitting posture can be categorized into anterior (forward), middle, and posterior (backward) sitting positions.

- Division based on location of COM of the body and affects the proportion of the body weight transmitted to the different support surfaces.

  - Middle: COM directly over *ischial tuberosities (IT)* and floor supports 25% of body weight (BW).

  - Forward: COM in front of IT and floor supports more than 25% of BW.

  - Backward: COM behind IT and floor supports less than 25% of BW.
Disc pressure during sitting

Figure 9.12  Disc pressure measurements in standing and unsupported sitting postures. (Adapted from Andersson et al., 1974.)
Modifications to the standard computer work posture

- Recommended thigh-back angle (to spread the load on the buttock-chair surface and prevent lordosis (exaggerated lumbar curvature)): 135°
- Induces shear force between buttocks and seat: counterbalance by a tibial pad that induces an equal and opposite horizontal force component
Upper spine posture during sitting

- The upper back and neck posture can also greatly vary during sitting
- Two main angles of study:

  1) Upper back sagittal plane rotation (kyphosis)
  - Can be especially aggravated when the arms are working in front of the body (e.g., computer work)
  - Can be measured using motion capture by measuring the rotation of a plane constructed around T10-T12
  - Can be modified with training (Pilates)
Upper spine posture during sitting

2) cervical posture

- combination of neck + head postures
  - In the usual “forward head” posture associated with computer work: the neck is flexed, and the head is protracted
  - Two different angles:
    - Neck posture: joint center: C7
    - Head posture: approximately the angle between the head (ear to eye) and neck (ear to C7) segments
Next step: study the iphone neck and upper spine posture...!
Standing vs. seated manual work: recent findings

- Antle et al. (Occup Ergon, G&P 2012): 34min manual task (box folding)
  - More lower limb blood flow when standing
  - More changes in lower limb blood pressure when standing
  - More neck-shoulder EMG amplitude and increase with time when seated
  - More lower limb discomfort when standing
  - More back and upper limb discomfort when seated
  - * make workplace recommendations based on location of symptoms
Standing vs. seated work: some practical recommendations

- **A standing posture** is preferable when:
  - heavy loads must be lifted
  - handling bulky objects
  - the task involves moving around frequently

- **A seated posture** is preferable when:
  - The task is of long duration
  - There is fine manipulative work or close visual work, or when the whole body has to be kept very still
  - When there are foot operated controls
IN THE NEWS: THE DANGERS OF SITTING!
THE SITTING DISEASE: WHERE DID IT START?

Avid gamer: Chris Staniforth died from a blood clot after sitting still for 12-hour sessions on his Xbox. He was passionate about computers posting this picture on his Myspace account three years ago.
THE SITTING DISEASE: WHERE DID IT START?

To treat obesity…! Mayo clinic study (Dr. Levine): Employees lost 10 kilos after a few months, but what does it do to the muscles?

https://www.youtube.com/watch?v=fmR6mB772zM
Trends in computer work ergonomics

- Seats that help promote (micro) movements: exercise balls, sit-stand stools
- Sit-stand computer workstations
- Walking, biking computer workstation

**Bottomline:**
- try to avoid prolonged static postures,
- go according to symptoms,
- but be careful, very few of these devices are evidence-based...!

That doesn't look very good for the neck and arms...!!
Standing computer work

- Part of collective agreements for several workforces (e.g. university professors and teachers) in Denmark is to have free access to standing computer workstations.

- Keep body close to the work surface
  - The neck, upper back and upper limb postures should be the same as for seated computer work (see ergonomic adjustment guidelines).

- Use a foot rail or portable footrest to shift body weight from one to the other leg.

- Use a floor pad for hard and/or cold surfaces.

- Adjust the workspace to get enough space to change working position (ideally, height adjustable table).

- Alternate seated + standing work, if possible.
BOTTOMLINE: Avoid static loads and fixed work postures

- Static loads are bad because of reduced blood supply to working muscles
- During work, both systolic and diastolic pressure increase much more rapidly if work is isometric, compared to rhythmic
- Consequence: bad tissue regeneration + swelling of the legs (extra work to pump the blood back to the heart & brain due to working against gravity)

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What are the effects on the musculoskeletal system?

• Computer work seated vs standing vs walking
• 90-min text copying task, comfortable walking speed
• Results:
  – Less neck-shoulder discomfort, less EMG amplitude, less co-activation, more variable muscle activity (*all signs of lower injury risk*) in both standing and walking (vs seated)
  – Walking did not affect computer work performance (speed, errors), performance actually improved during standing vs seated
  – Suggests that in addition to increased caloric expenditure, alternate computer work postures are also « good » for the neck-shoulder muscles but….
    • *Careful, we only studied one 90min work bout, in healthy young adults accomplishing a simple, low-concentration task*

This is getting out of hand…!

- https://www.youtube.com/watch?v=ZAjKk_SQBv4

  - The times of India: Treadmill work stations reduce pain….!?!?
  - https://www.youtube.com/watch?v=vNhJ4TlfeBM

- Forget the Standing Desk, Here’s What Science Says about the Treadmill Workstation", Business Insider Australia, July 9

- Why You Need a Treadmill at Your Desk…”, South China Morning Post, July 14

- “Treadmill Work Stations Reduce Muscle Pain”, News Everyday, July 9

- “Working Out in Office More Beneficial Than Thought”, The Health Site, July 8

- Working Wounded: Desk Labor Causes Injuries, Too”, HLNTV, July 10]

- [“Taking the Pain Out of Office Work”, Newswise, July 7]
Avoid the forward head posture

- Oftentimes related to visual fatigue, strain
- Solution 1: Set screen at optimal height
- Solution 2: change font size

Be careful with neck rotation

- Set the screen parallel with shoulders
- Can be a problem with multiple screens

Avoid neck lateral flexion

- Can be the source of head and upper limb problems
• Walk & work on Ellen Degeneres
  – https://www.youtube.com/watch?v=zQme8wBglMs
**Ergonomics for Adults:**
- Monitor at eye level
- Keyboard at elbow height
- Lumbar support chair

**Ergonomics for Kids:**
- Monitor at eye level
- Keyboard at elbow height

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*XY-BITS*

**LET'S GET YOU ERGONOMIC FOR BETTER PRODUCTIVITY, OK?**

**1.** Feet flat on floor.

**OK, GOOD—STEP TWO: ARMS RELAXED, FOREARMS LEVEL WITH WORK SURFACE.**

**THERE, NOW—STEP THREE: EYES LOOKING STRAIGHT AT MONITOR.**

**GOOD, NOW HOLD THAT 'TIL LUNCH.**
REFERENCES


Vieira MF1, de Avelar IS1, Silva MS1, Soares V1, Lobo da Costa PH2. Effects of four days hiking on postural control. PLoS One. 2015 Apr 22;10(4):e0123214.


