The Science of Shear

and Research-Based Implications

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Speaker Biographies/Disclosures

Ana Endsjo MOTR/L, CLT worked as an occupational therapist beginning in 2001 in a variety of treatment settings including: acute care, sub-acute care, outpatient, acute rehab, long term care, and as a lymphedema certified therapist. She has worked mostly with the geriatric population, focused on seating and positioning and contracture management of the nursing home resident.

In January 2016, she started with Comfort Company as the Clinical Education Manager for the long term care division and then joined the Permobil family in October 2017 as Clinical Marketing Manager. In this role, she developed an education program for long term care settings with the hopes to guide other therapists, rehab directors, nurses, and administrators to understand the critical role proper wheelchair positioning plays in the prevention and treatment of serious health complications within long term care centers.

Speaker Biographies/Disclosures

Mark Payette CO, ATP is a certified orthotist and ATP with 24 years of direct patient care experience providing custom orthotic seating services for children at Gillette Children's Hospital, and then in private practice for children and adults, with Tamarack Habilitation Technologies, Inc. Following that, he has been working in product development for 12 years at Tamarack, focusing on developing friction management and custom wheelchair seat surface technologies.   His experience includes presenting lectures and workshops at the local, national and international levels.

Sharath Nair BS (Engr.) is a mechanical engineer. He obtained his degree in Mechanical Engineering in 2017 at the University of Minnesota. He has worked for Tamarack since 2017.

Mark and Sharath are employees of Tamarack Habilitation Technologies, Inc, which developed and manufactures GlideWear, ShearBan, and ENGO low friction technologies, and FlexForm.

Learning objectives

1. The participants will be able to list and define the extrinsic risk factors that lead to pressure injuries, within the context of intrinsic factors.
2. The participants will understand how the surface traction of friction causes shear deformations in soft tissue and why damaging levels of shear persist after the body has settled to rest.
3. The participants will be able to describe at least three research-based clinical management strategies for controlling friction between the weight bearing surface and a sitter and describe how doing so will reduce shear loads against the skin and deep tissue.

Pressure Injuries - **USA Impact on Health System**

NPUAP Definition: Pressure Injury

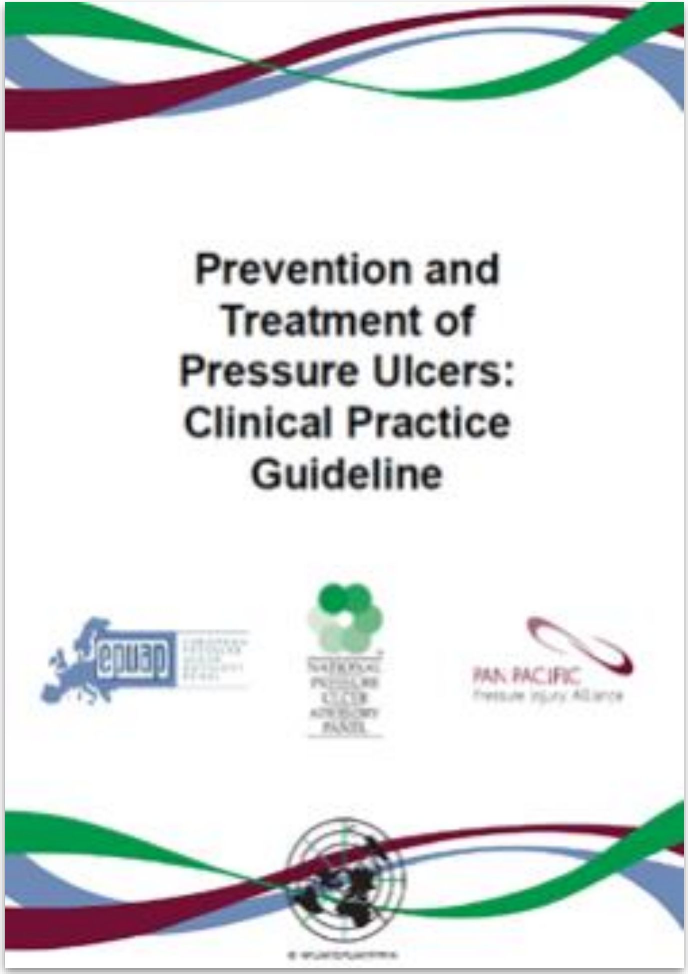
A pressure injury is localized damage to the skin and/or underlying soft tissue usually over a bony prominence or related to a medical or other device. The injury can present as intact skin or an open ulcer and may be painful. The injury occurs as a result of intense and/or prolonged pressure or pressure **in combination with shear**. The tolerance of soft tissue for pressure and shear may also be affected by microclimate, nutrition, perfusion, co-morbidities and condition of the soft tissue.

April 13, 2016:

http://www.npuap.org/national-pressure-ulcer-advisory-panel-npuap-announces-a-change-in-terminology-from-pressure-ulcer-to-pressure-injury-and-updates-the-stages-of-pressure-injury/

Highlight is not from NPUAP, but by authors

NATIONAL PRESSURE ULCER ADVISORY PANEL



Etiology

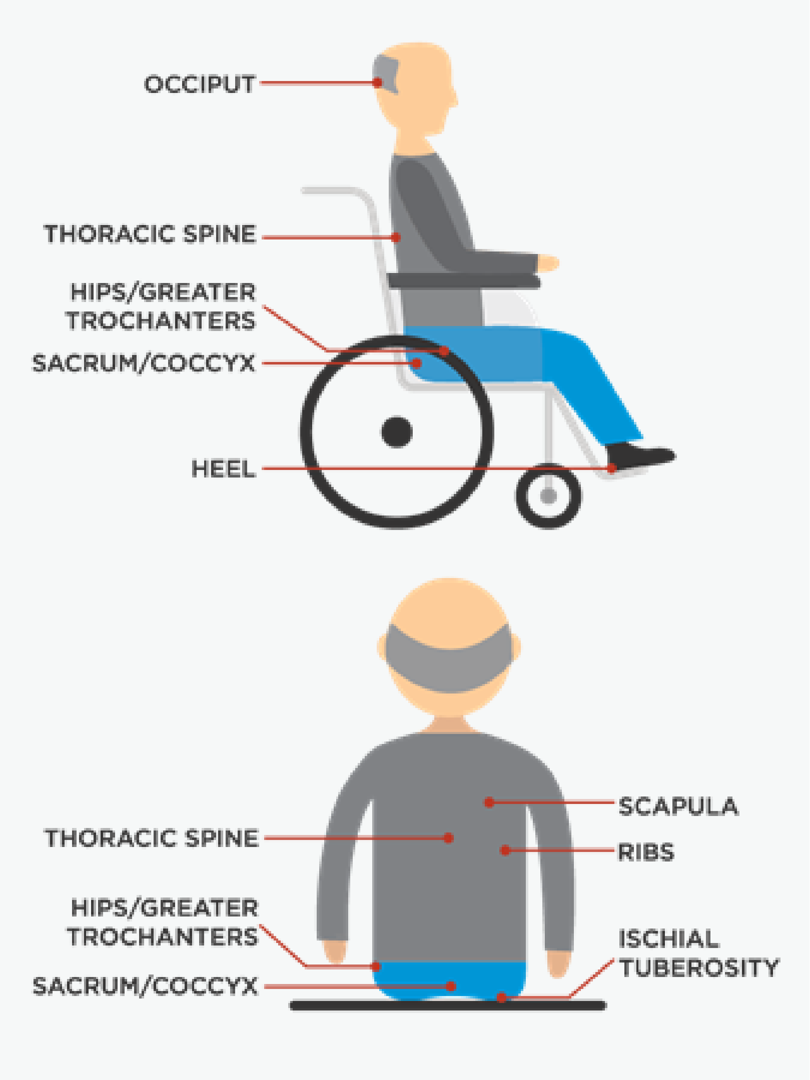
“Pressure ulcers develop as a result of the **internal response to external mechanical load.** Understanding the etiology of pressure ulcers relies on an awareness of the internal response to mechanical load and not just what is apparent on the outside of the body or on the skin surface.”

Mechanisms

An increasing body of evidence suggests two physiologically relevant deformation thresholds exist. One is a lower threshold leading to **occlusion of blood vessels** resulting in ischemia-induced damage and the other is a higher threshold leading **to direct deformation-induced damage.**”

Common Areas of Skin Breakdown

Wound Development at any of these areas can be classified in one of the stages of pressure injuries as defined by the NPUAP / EPUAP / PPPIA.



Intrinsic Factors of Wound Development

Factors stemming from within the body that make an individual more susceptible to wound development

- Age related skin changes
- Poor nutrition and dehydration
- Urinary and fecal incontinence
- Limited mobility
- Impaired sensation
- Orthopedic deformities
- Postural deformities
- Medical conditions affecting blood flow
- Obesity
- Being Underweight
- Limited Alertness
- Muscle Spasms
- Smoking

Extrinsic Factors of Wound Development

Factors that stem **from the external physical environment of seating design**

The therapist can reduce the harmful effects of extrinsic factors through proper wheelchair positioning and equipment choices

Relationships Between Extrinsic Factors and Internal Soft Tissue Conditions

Pressure, shear and microclimate co-exist and are linked together

Prolonged pressure creates ischemia at the cellular layer and tissue deformation

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+ Friction =

Friction, in combination with pressure, significantly increases the development of shear stress/strain within the tissues (resulting in tissue deformation)

Prolonged pressure creates ischemia at the cellular layer and tissue deformation

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Prolonged pressure creates ischemia at the cellular layer and tissue deformation

= ↑

Microclimate, including localized temperature and moisture, influences the susceptibility of skin and soft tissues to the effects of pressure, shear, and friction

- Moisture reduces epidermis corneum strength (fractures easier)
- Moisture increases coefficient of friction (increased traction on skin)
- Better evaporation cools, reducing cell metabolic rate (cells live longer)
- Extremes of localized temperature reduces epidermis corneum strength (fractures easier)

Understanding

SHEAR

The Silent Extrinsic
Factor

Definitions

Shearing Stress [MECH] A stress in which the material on one side of a surface pushes on the material on the other side of the surface which is parallel to the surface. Also known as shear stress; tangential stress.

Shearing Strain [MECH] The distortion that results from motion of material on opposite sides of a plane in opposite directions parallel to the plane.

Friction [MECH] A force which opposes the relative motion of two bodies whenever such motion exists or whenever there exist other forces which tend to produce such motion (is essentially consistent with the International Review definition). (Also referred to as Shear Force)

Kinetic Friction (Dynamic friction) [MECH] The friction between two surfaces which are sliding over each other.

Static Friction [MECH] 1. The force that resists the initiation of sliding motion of one body over the other with which it is in contact. 2. The force required to move one of the bodies when they are at rest. Also known as limiting friction, starting friction.

Shear:
Shear stress results from the application of a force parallel (tangential) to the surface of an object while the base of the object stays stationary

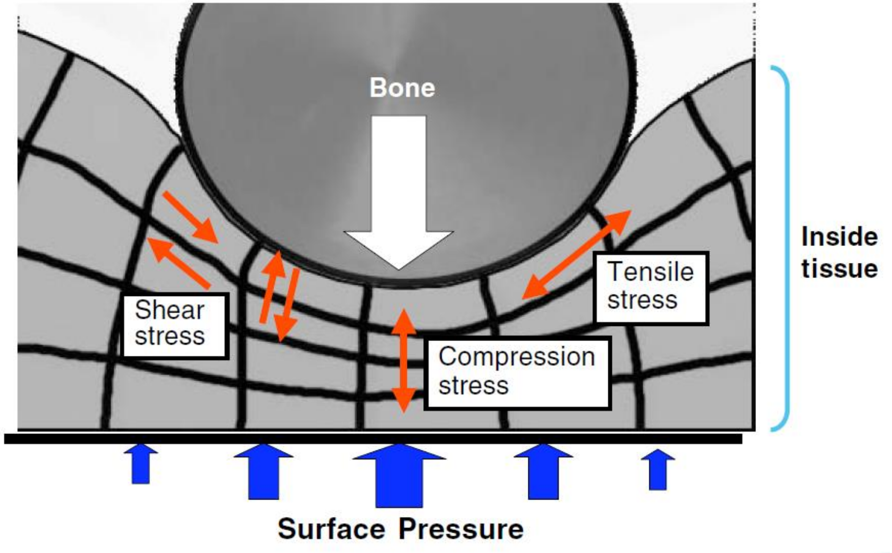
Shear stress causes the object to change shape (deform). The amount of deformation caused by shear stress is quantified as shear strain.

Friction is defined as the force that resists the relative motion of two objects that are touching.

McGraw-Hill Dictionary of Engineering, 2nd Edition, 2003
International Review: Pressure, shear, friction and microclimate in context - A consensus document, London: Wounds International, 2010.

Shear: What DO we know?

Distribution of stresses inside tissue from the view of biomechanics.

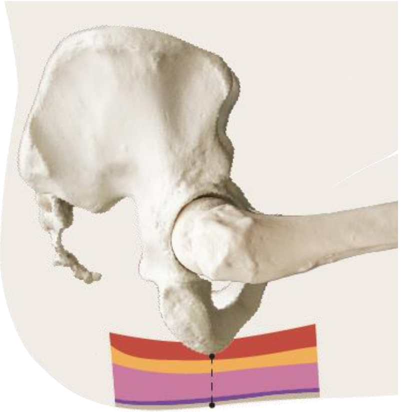


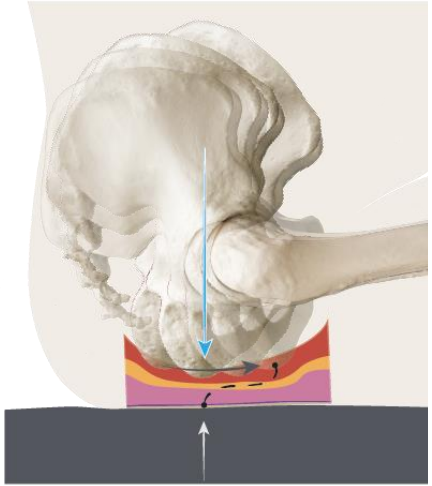
Even when only pressure is applied (ie: the force applied is only perpendicular), tensile and shear stresses also occur within the tissues near bony prominences.

International Review: Pressure, shear, friction and microclimate in context - A consensus document, London: Wounds International, 2010.

NPUAP Shear Force Slide set. (n.d.). Retrieved January 23, 2019, from http://www.npuap.org/resources/educational-and-clinical-resources/shear-force-slide-set/

The mechanics of **SHEAR**





Gravity causes downward pressure

The sitting person moves/slides in the chair

The skin/tissue at the seat surface DOESN'T move while the underlying bone structure DOES

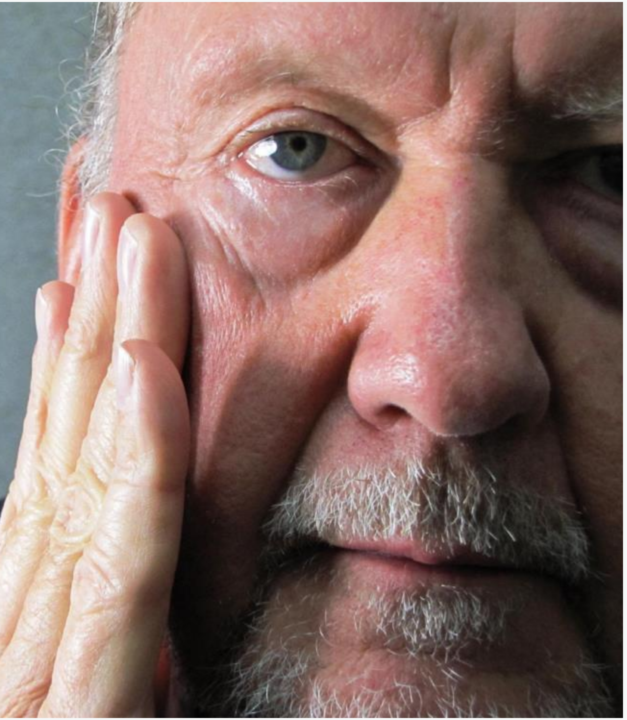
The skin/tissue is strained by the forces from friction (shear force)

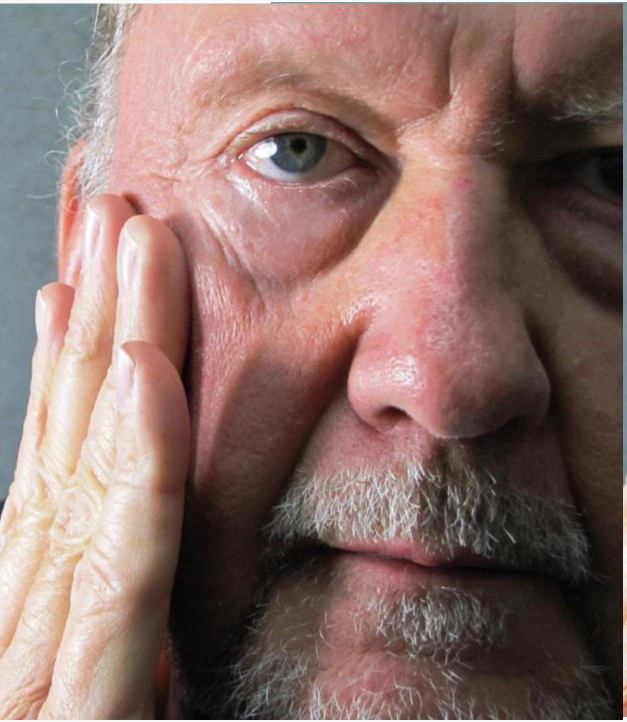
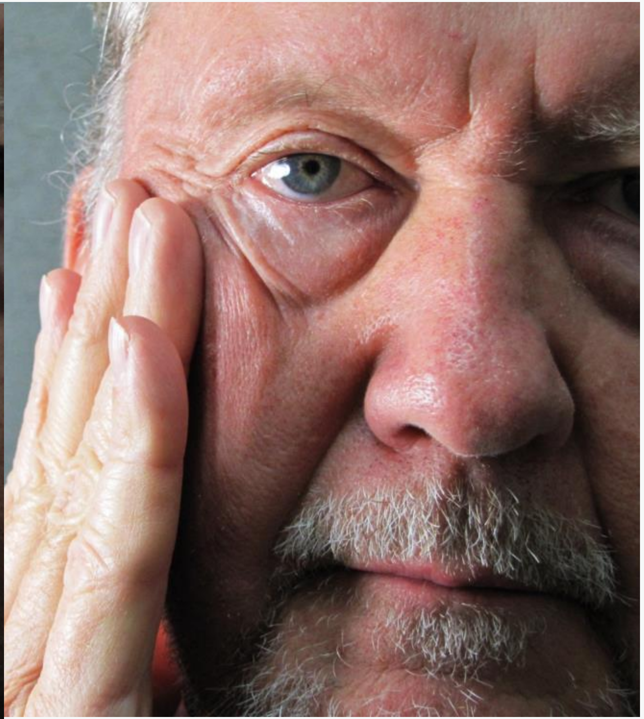
Causing tissue deformation at the deeper layers of tissue

Blood vessel damage decreases oxygen delivery

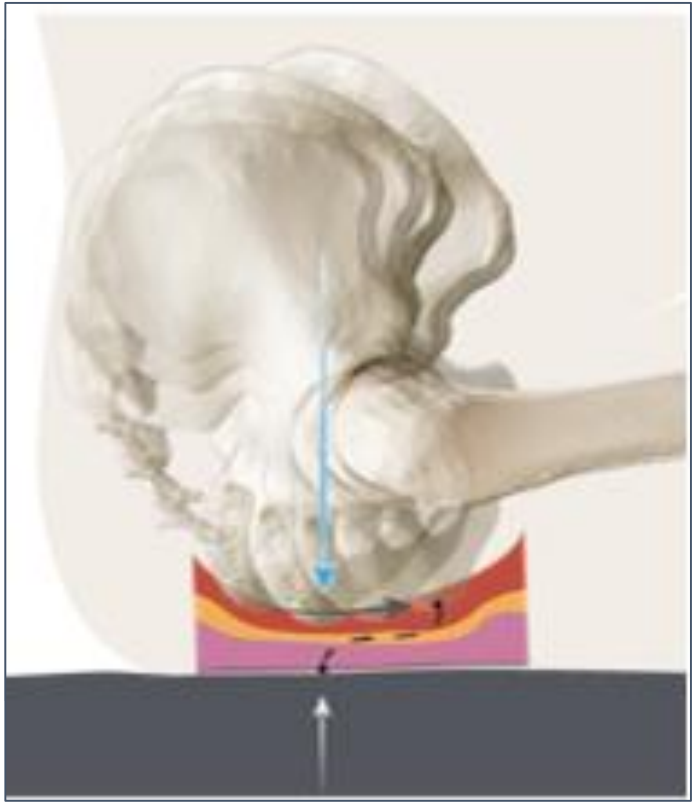
Exacerbates ischemia

Tissue Death



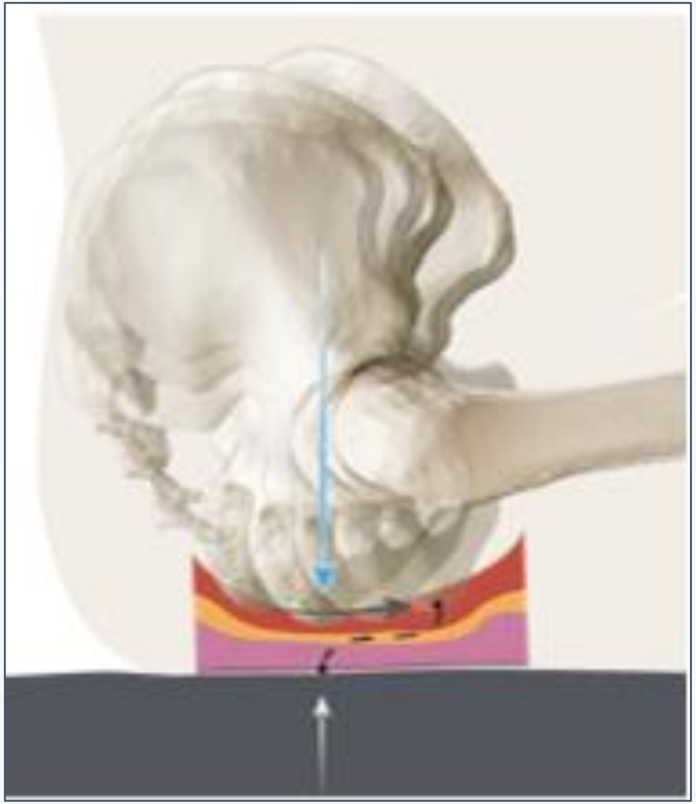



Clinical Relevance: Understanding Shear "Shear What??"



- Shear is commonly misconceived to be friction alone
- It occurs while the person sitting in the chair is moving intentionally and/or unintentionally

Clinical Relevance: Understanding Shear "Shear What??"



- Shear is commonly misconceived to be friction alone
- It occurs while the person sitting in the chair is moving intentionally and/or unintentionally

When does shear occur while sitting?

- Sitting still
- Transfers
- Settling into position following a transfer
- Sliding into an abnormal posture due to an ill-fitting wheelchair system
- Agitated resident that is constantly shifting
- Repositioning multiple times in the wheelchair system
- Bending or reaching while in the wheelchair
- Propelling
- Toileting and dressing functions

Scar tissue and adhesions

represent especially dangerous situations as they will see ‘limiting friction loads’ very quickly

Wound recurrence?

We know that when successful, the wound is considered ‘closed’ – it is not ever considered ‘healed’ - and remain very vulnerable to recur

Manage ALL extrinsic factors:

-Reduce pressure as always / usual

-Damage to tissue is difficult to prevent without reducing friction (lower CoF) in the specific area

-If possible, keep the area ‘normal’ relative to moisture and temperature (microclimate)

Definitions (Engineering)

Coefficient of Friction:

A measurement of the amount of friction existing between two surfaces for a given force tending to hold the surfaces together.

The COF depends on both of the materials in contact

Moisture content of the skin or fabric may increase the COF

NPUAP Shear Force Slide set. (n.d.). Retrieved January 21, 2019, from http://www.npuap.org/resources/educational-and-clinical-resources/shear-force-slide-set/

Video demonstration of COF difference

Definitions (Engineering)

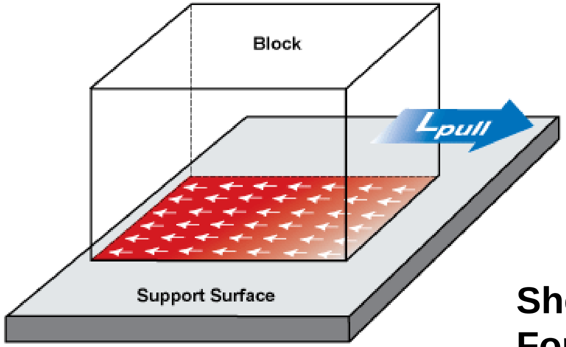
Limiting Friction See static friction.

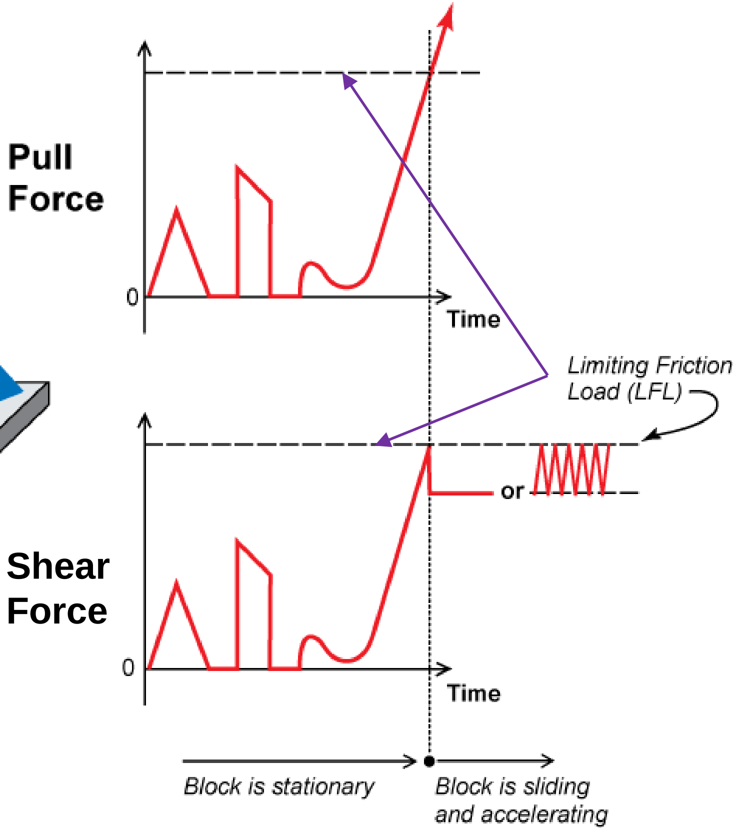
Static Friction[1] [MECH] 1. The force that resists the initiation of sliding motion of one body over the other with which it is in contact. 2. The force required to move one of the bodies when they are at rest. Also known as limiting friction, starting friction.

Determines when movement begins

McGraw-Hill Dictionary of Engineering, 2nd Edition, 2003

Limiting Friction Load (LFL) is the point at which enough tangential force is present to overcome static friction – movement begins (the ‘load’ changes from a static to a kinetic condition)





$LFL = L_n \times CoF$

Clinical Relevance: **Kinetic** (dynamic) and **Static** Conditions

Kinetic (Dynamic) Condition

- Sliding / transferring and movement over a support surface whether intentional or not
- Can result in frank abrasion of epidermal tissue

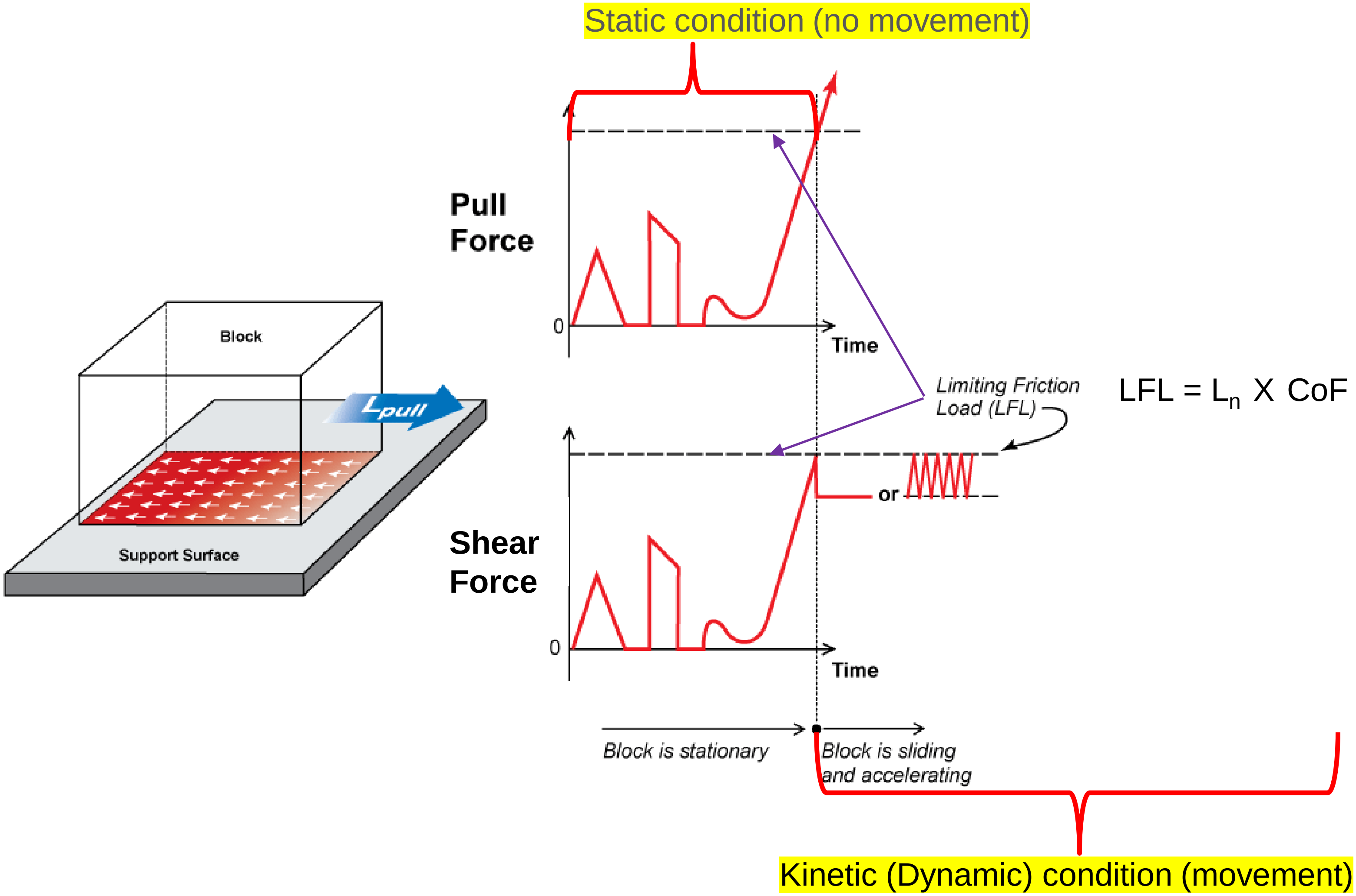
Is OBVIOUS

Static Condition

- Propelling, reaching, rotating trunk are examples of 'micro movements' that happen while sitting (or laying) (but the person is not literally moving on the surface. Soft tissue is distorted back & forth but may not be sliding

- The skeleton is inside the 'bag of skin' and moves relative to the exterior (no literal sliding movement at the surface occurs)

Is NOT obvious



Static condition (no movement)
Block
Lpull
Support Surface
Pull Force
0
Time
Limiting Friction Load (LFL)
LFL = Ln X CoF
Shear Force
or
0
Time
Block is stationary
Block is sliding and accelerating
Kinetic (Dynamic) condition (movement)

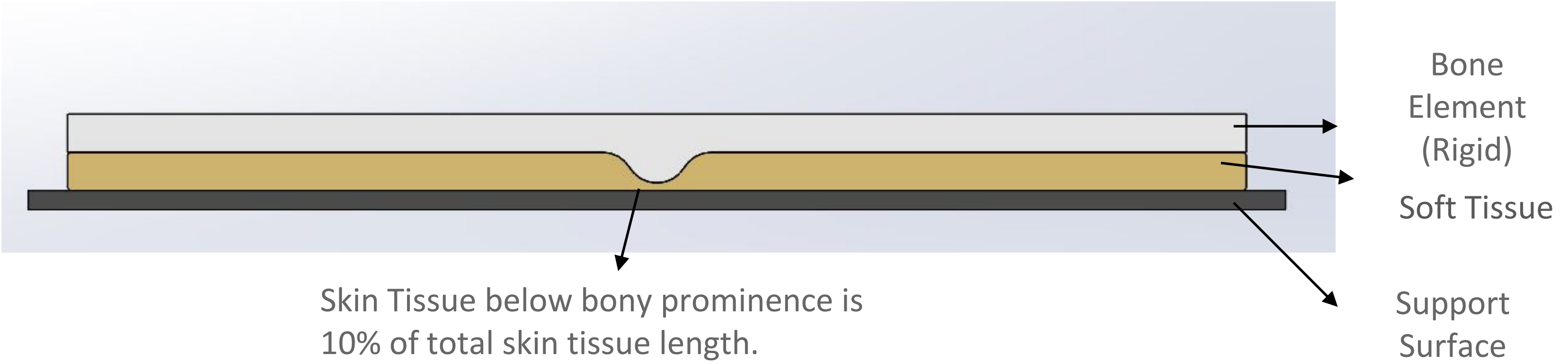
Video demonstrating CoF difference, LFL, and tendency to slide

Finite Element Analysis: Objectives

- To develop a virtual biomechanical model for finite element analysis (FEA) software.
- To illustrate how the addition of a surface traction force (friction) to a compressive load, effects the magnitude and locations of shear stress & strain within the soft tissue under and near a bony element.
- The developed FEA model is a simulation in principle to address the correlation between strategic friction reduction and maximum shear stress within the soft tissue.
- This model is to be valid in only a very basic way. It approximates a rigid skeletal structure covered by soft tissue. The soft tissue is quite thick over most of the structure except for where it covers a single prominence.

Model

- Model was developed on SOLIDWORKS Simulation Software
- Simplified representation of three material elements & two interfaces:
    1) Bone Element
    2) Soft Tissue
    3) Support surface



- Strategic friction reduction under one at-risk (bony) site.

Model Assumptions

1. Follows assumptions of linear elastic analysis.
2. Soft tissue was assumed to be uniform and isotropic.
3. Bone & support surface modelled as rigid bodies.
4. Soft tissue bilateral boundary conditions are free and unconstrained.

Model Materials & Constraints

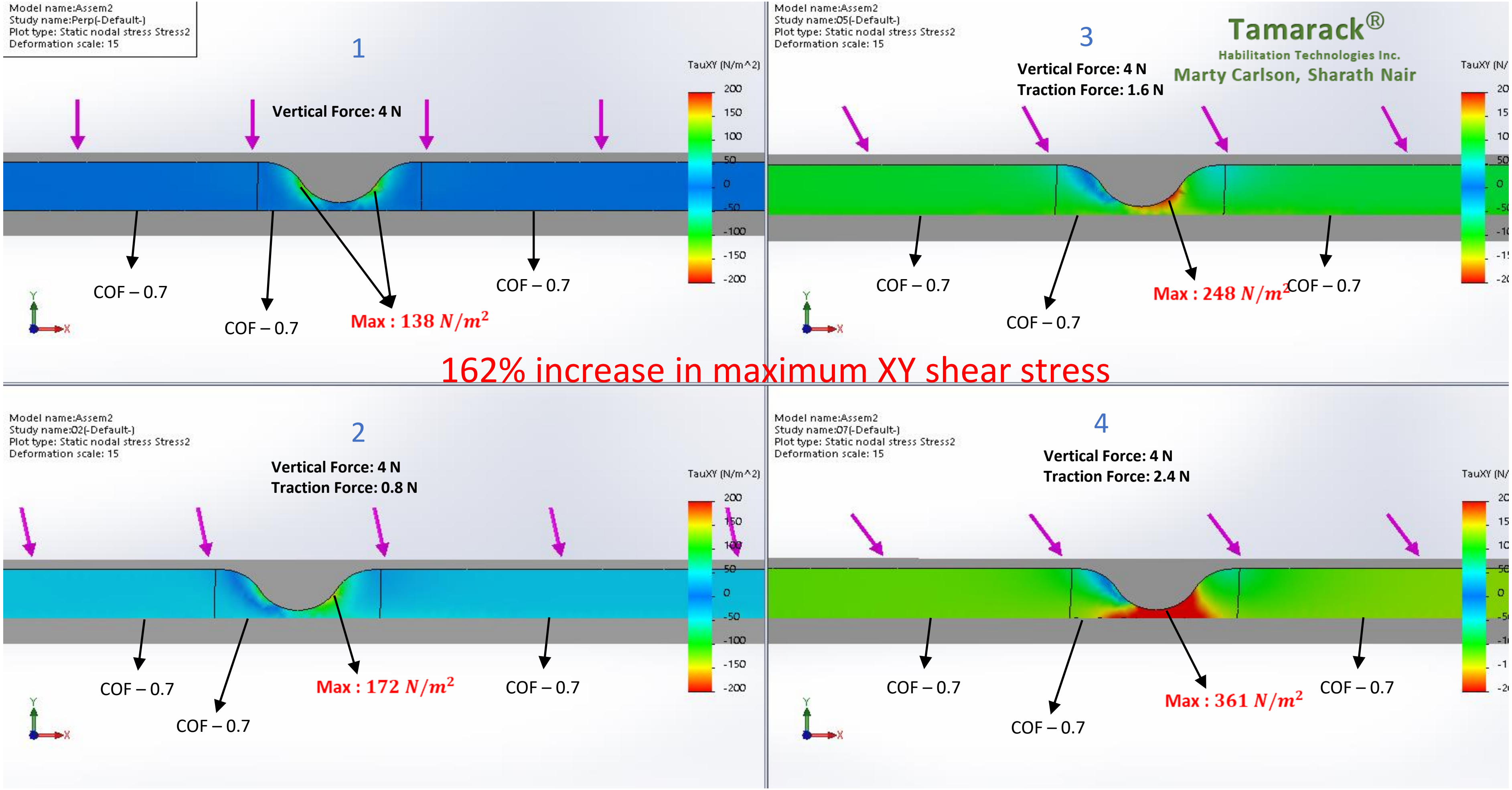
- Model Materials
  - Support surface & bone element have been modelled as having a very high elastic modulus (Rigid Body Approx.)
  - Soft tissue modelled with following properties:

Yield Strength: 0.13 psi
Elastic Modulus: 10 psi
Poisson's ratio: 0.01
Mass density: 0.036
Shear Modulus: 420 psi

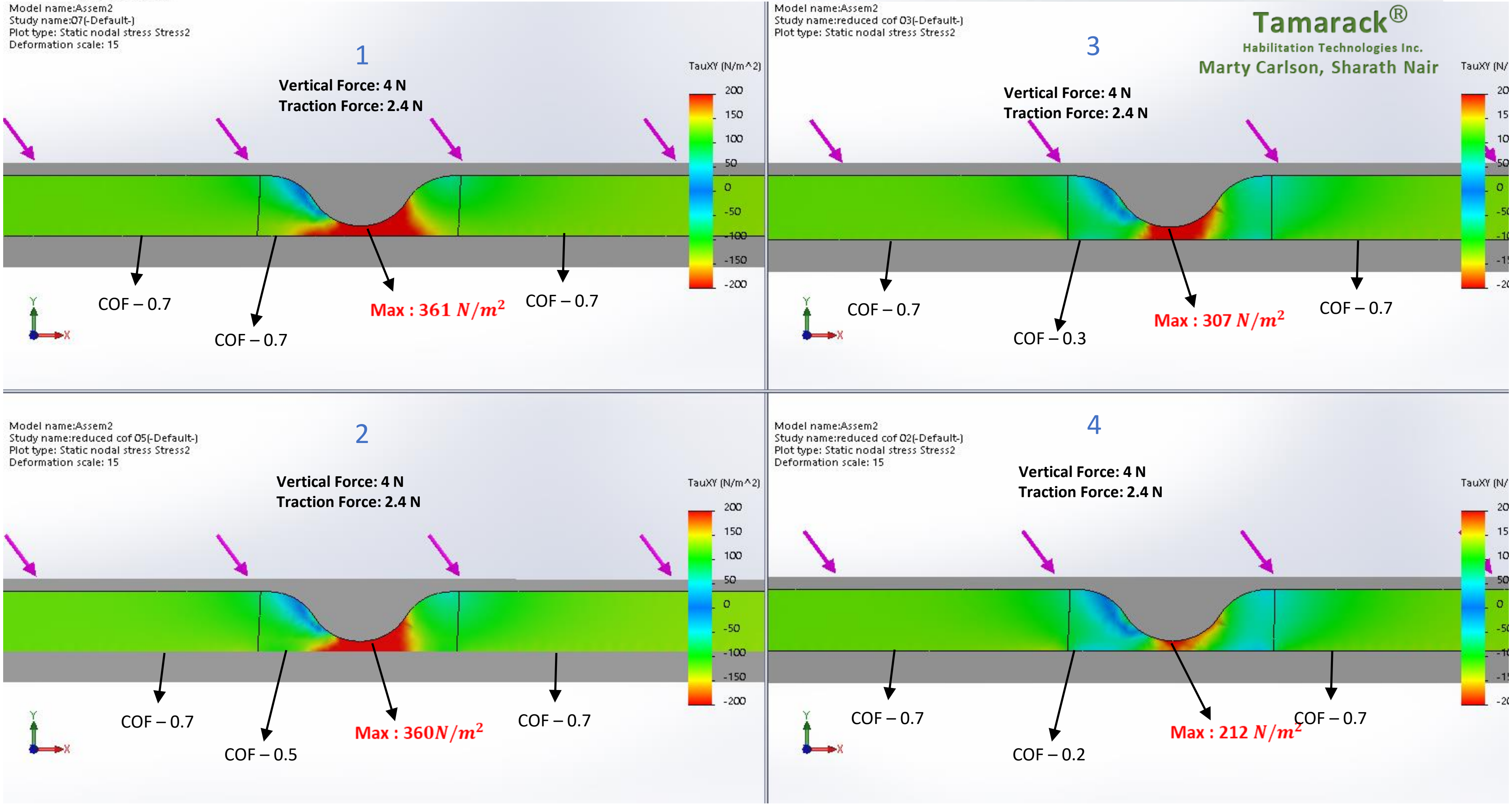
- Constraints
  - Bonded contact for soft tissue-bone interface.
  - Soft tissue-support surface COF = 0.7 unless otherwise specified.
  - Fixed geometry constraint for bottom of support surface.

- Following Shear plots focus in for clarity on what happens within the central portion (under bony element) of the model.

Maximum XY Gradient Shear Stress Comparison plots (Magnified View of Bony Prominence)



Strategic COF reduction- Max XY Shear Plots (Magnified View of Bony Prominence)



- XY shear stress plots are used, as maximum shear stress relative to this plane is the main contributor to skin breakdown. It is the plane along which blister formation takes place due to breakage within the spinosum layer of the dermis.

- In Quasi Static Loading conditions, the perpendicular load (pressure) has been generally considered as the **main contributing factor** for breakdown of the soft tissue. This study illustrates that while pressure is a friction facilitator, **friction load increments** seem to be strongly related to shear stress/strain within the soft tissue.

- **Strategically reducing the COF** along the skin-support surface interface can reduce the shear stresses known to be a factor in soft tissue breakdown.

Next Steps

1. Explore the effect of changing the size of the strategic friction reduction area to judge how large the strategically reduced COF should be.

2. The model can be made more sophisticated by including :
   - Separate skin material with relevant mechanical properties at soft tissue surface
   - A contoured support surface

3. This study addresses the basic concept of reducing internal shear stresses using local strategic friction reduction. However, to yield more precise & valid results, future FEA analysis will entail more **anatomy specific modelling** and a **software more suited to statically indeterminate structures/combinations.**

4. Experimental and analytical investigations regarding the role of friction induced shear should and will continue but we must also begin **applying available COF reduction technologies** to develop best practices. This FEA work is an attempt to begin to analytically demonstrate and guide our strategic friction reduction (SFR) designs.

Clinical Relevance:
Is there ‘good’ and ‘bad’ friction (shear force)?

BAD

- Friction can create destructive shear stress in locations where it is not tolerated such as:
  - Where a bony prominence is close to the surface of the skin
  - Where there is limited mobility in the skin and especially
    - Scar tissue / grafts
    - Adhesions / tethering

GOOD

- Friction (and the resulting shear stress) can be present for stability and function without being injurious in areas where there is plenty of soft tissue and space between the bony prominence and the skin surface, and where there is sufficient tissue mobility to absorb the shear stress
  - Provides traction and stability for function and positioning

Clinical Relevance:
Is there ‘good’ and ‘bad’ friction (shear force)?

A strategy to balance Good and Bad shear forces

Reduce friction locally <u>where it is damaging to tissues</u>

- Easy to use an interface (this is where CoF is important)
- Interface can be incorporated onto a support surface
- Interface can be garment based (worn by the individual)
  - Broader protection is provided when user is not on the support surface
    - During transfers
    - On less safe support surface (automotive / recreation vehicles, furniture, floor, etc.)

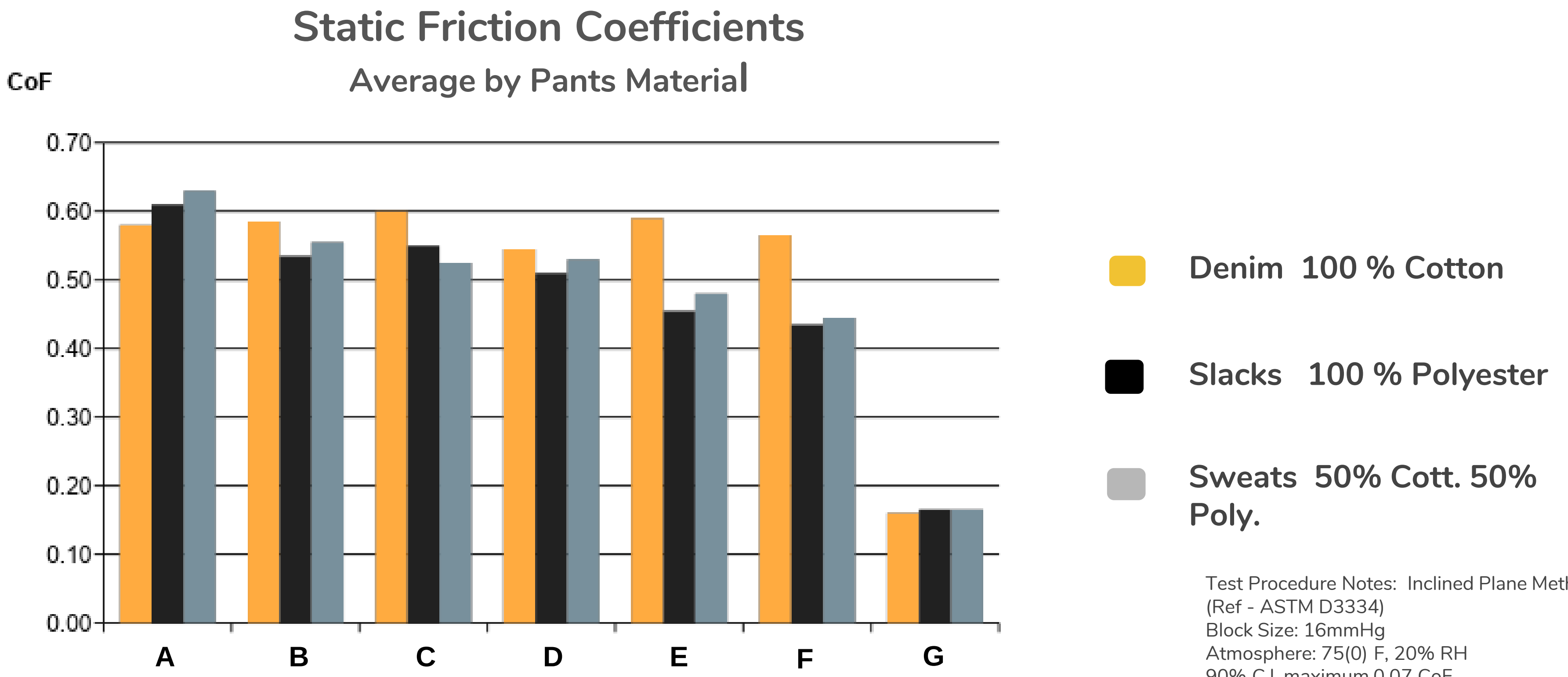
Strategic Friction Reduction (SFR) is analogous to offloading PRESSURE ***

Interface Video Demonstration

No Interface

Low Friction Interface

Coefficient of Friction in Typical Wheelchair Seat Cushions and Cushion Covers



Average values a-p and m-l per pair of materials researched

Test Procedure Notes: Inclined Plane Method
(Ref - ASTM D3334)
Block Size: 16mmHg
Atmosphere: 75(0) F, 20% RH
90% C.I. maximum 0.07 CoF

Combined Intrinsic and Extrinsic factors

Intrinsic -

Age related skin changes
Nutrition
Urinary and bowel
Mobility
Sensation
Medical conditions
Weight
Alertness
Smoking

Extrinsic -

Prolonged Pressure -
causes ischemia and cellular and tissue deformation

Shear -
combination of pressure and friction induce shear forces

Microclimate -
moisture and temperature weakens the skin and increases the effects of pressure and shear

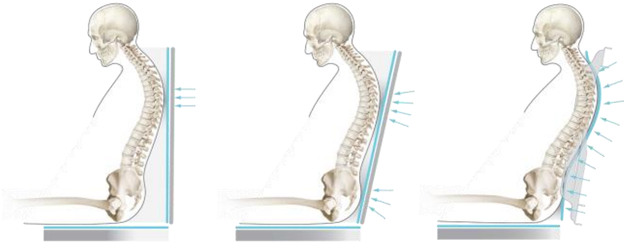
The link is real; as clinicians, manage the extrinsic factors for all clients presenting with ANY of the intrinsic factors

Research-Based Clinical Management Strategies

Identification of those at risk for pressure injury

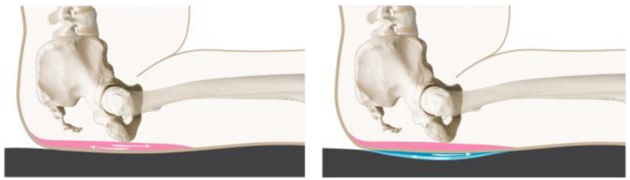
Avoiding tissue distortion by:

- Considering Wheelchair Configuration to prevent unwanted movement (create stability and alignment by cradling of body by support surfaces and matching the residents ROM)

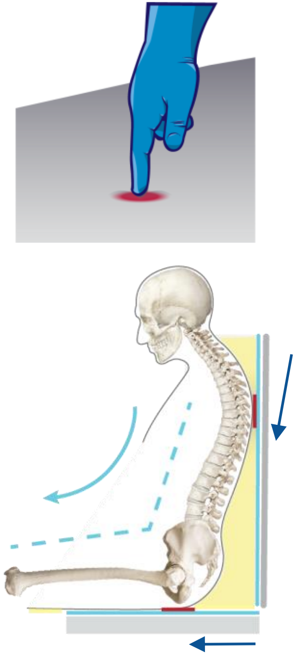


- Increasing contact area with support surfaces

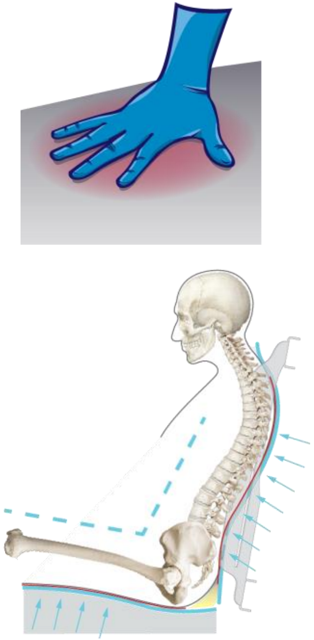
- Strategically using very low lower coefficient of friction interfaces



Appropriate angles and contour: provide stability, alignment and pressure redistribution



Peak pressure and strong tendency to slide



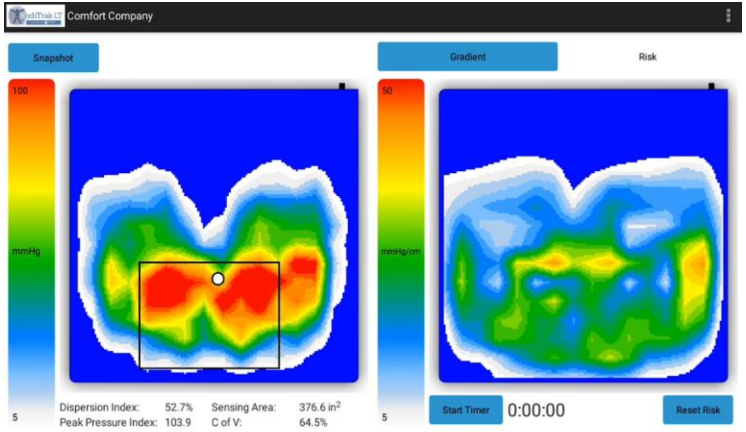
Increased surface contact for pressure redistribution and reduced tendency to slide

Case Example

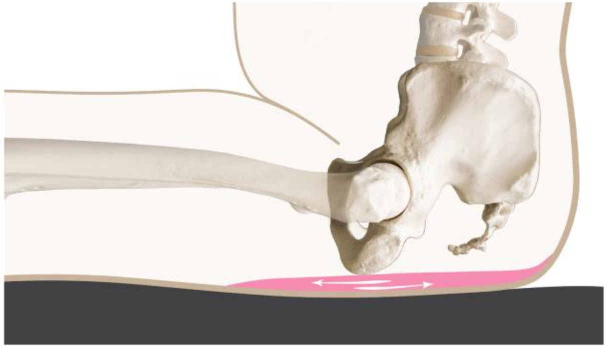
Increasing Surface Contact Area

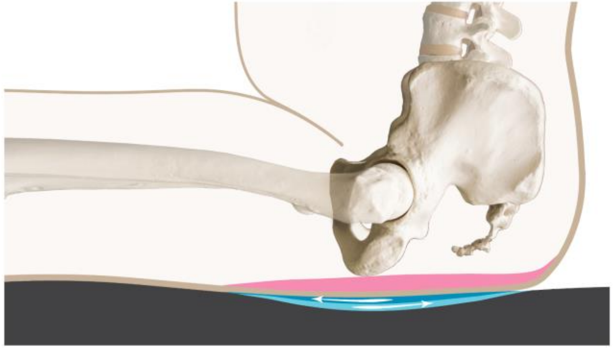
Increasing Surface Contact - Opening STBA

Increasing Surface Contact - Removing ELR

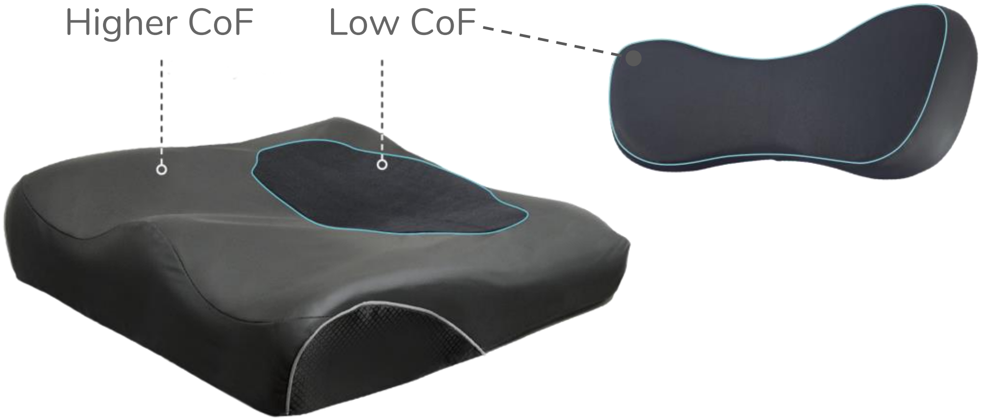


Low Friction Interface





High CoF Surface



Questions / Key takeaways

All extrinsic factors should be considered every time from the start (don't only address pressure, don't wait for a problem)

Relationship between Friction and Shear

Shear strain describes tissue deformation ('sliding' is not a complete/accurate picture)

Reduce shear strain risk clinically through supportive positioning (reducing tendency to slide) and use of <u>strategic</u> (not everywhere) low-friction interfaces

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