Simulations of tissue loads in the seated buttocks on an air-cell-based cushion in bariatric/diabetic wheelchair users

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Category 1: Changes in skin

Category 4: full thickness skin loss; fat and muscle damage; bone is exposed
Distinct mechanisms of deep versus superficial pressure ulcers

Superficial Pressure Ulcers

Extrinsic
- Moisture and heat
- Friction properties

Intrinsic
- Impaired motosensory capacities
- Poor nutrition
- Infection

Superficial pressure ulcers

Deep Tissue Injury (DTI)
(Black et al., 2005)

Extrinsic
- Posture, Time at posture
- Stiffness of the support

Intrinsic
- Impaired motosensory capacities
- Muscle atrophy

Progressive necrosis

Deep tissue injury

Superficial pressure ulcers at the buttocks

DTI under the ischial tuberosities
Exposure to deformations kills cells and tissues fast! Much faster than ischemia

**Conclusion:** support surfaces and devices for prevention should minimize internal tissue deformations and loads, not (just) interface (skin) pressures!
Adequate envelopment minimizes tissue deformations

![Diagram showing muscle deformation over time with different levels of envelopment.](image)

- **No envelopment**
- **Medium envelopment**
- **High envelopment**

**Muscle deformation [%]**

**Time [hours]**

**Death of muscle tissue**

**Viable muscle tissue**

Added safe sitting time through greater envelopment

Cell death tolerance of Gefen et al. (2008)
Example: Greater envelopment substantially reduces localized tissue loads during wheelchair sitting

Air-cell-based (ACB) cushion

Flat foam cushion

stiffness = 10 kPa

Ley et al. Journal of Tissue Viability 2014
Integrate previous modeling concepts with pathoanatomical and biomechanical tissue changes that result from obesity and diabetes…

…to determine how a support surface might reduce this risk.
• Sopher & Gefen (2010) used FE models to investigate how BMI variations influence tissue loads on flat foam cushions

• Shoham & Gefen (2015) used the same method to explore how fat mass affects tissue loads on contoured foam cushions

• Both studies reported a considerable increase in muscle strains/stresses with increased levels of BMI or fat mass
Model variants to simulate weight gain while sitting on an ACB cushion

Ref
F
IT
G

+10% Fat

+20% Fat

+30% Fat

+40% Fat
Skin tissue stresses in diabesity models

Diabetic skin and fat tissues were considered as **being 40% stiffer** than non-diabetic tissues according to the literature.

The locally increased soft tissue stiffness in skin and fat imposes the risk of elevated tissue stresses, while also subjecting nearby tissue segments to an **increased risk of deformation-inflicted injury**.
Muscle tissue stresses in weight-gain models

Volumetric exposure to elevated gluteal muscle tissue stresses increases as bodyweight rises.
ACB cushions keep the effective average strain/stress values from exceeding a +20% increase for up to +20% increase in fat mass (equivalent to BMI of 30)
Tissue stresses in the “worst case” diabetic, obese simulation seated on an ACB cushion, were a fraction of the stresses reported in the literature for “best case”, non-obese, non-diabetic simulated subjects on foam.

Through immersion and envelopment, this risk of diabesity was substantially reduced by the ACB cushion.
• Previous research demonstrated that strains and stresses in weight-bearing tissues of the buttocks significantly increase with rise in body or fat masses.

• However, the ACB cushion was able to dramatically counter this pathophysiological risk factor of diabesity.

• The ACB cushion's adaptability and adjustability allow it to conform to a variety of anatomies and pathophysiological changes, including this often overlooked risk factor of diabesity.
A Computer Modeling Study to Evaluate the Potential Effect of Air Cell-based Cushions on the Tissues of Bariatric and Diabetic Patients

Ayala Levy, MSc; Kara Kopplin, BSc; and Amir Gefen, PhD

Abstract

Sitting-on-surface pressures (SOPS) are a potentially life-endangering complication for wheelchair users who are obese and have diabetes mellitus. The increased body weight and diabetic-related alterations in weight-bearing tissue properties have been identified in the literature to increase the risk for PLIs, ulcers, and pressure injuries (PIIs). A computer modeling study was conducted to evaluate the biomechanical effect of an air cell-based (ACB) cushion on tissues with increased fat mass and diabetes, which causes altered stiffness properties or compressive tissues with respect to healthy tissues. Specifically, 10 finite element (FE) computer simulations with the CogPlan model and their strain and deformation magnitudes were considered on measures of the tissue's PLIs, PIs, and PIIs to assess the effects of fat mass and pathological tissue properties on the effective strain at the interface tissues during sitting on an ACB cushion. The FEA modeling captured the anatomy and load-bearing capacity of an individual with a specific body habitus. The ACB cushion facilitated a more robust increase in tissue strain (p < 0.05) and strain (p < 0.05), and this effect was more pronounced in the affected tissues area with the increase in fat mass, for both diabetic and non-diabetic conditions. These simulation results suggest that wheelchair users who are obese and have diabetes may benefit from using an ACB to minimize the increased mechanical strains and strains in the weight-bearing tissues in the shoes that result from these conditions. Clinical studies are needed to understand the interaction between cushioning properties and diabetics with the development of PLIs and PIs, as well as to determine the optimal cushioning properties and the development of PLIs and PIs as well as to improve clinical presentation and comfort, and further the cushioning properties for wheelchair users and other wheelchair-bound individuals.

Keywords: wheelchair, support surface, diabetes, diabetes, finite element modeling

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Questions?