

Comparative effects of posture on pressure and shear at the body-seat interface

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Abstract—This study considers the effects of seated posture and body orientation on the pressure-distribution and surface shear (tangential) forces acting at the body-seat interface. Nine postures typically assumed by wheelchair users were studied. Comparisons were made within and between two study groups, made up of 12 subjects with spinal cord injuries (SCI) and 10 nondisabled subjects. Both interface pressure and the surface shear were measured simultaneously in each of nine reproducible, seated postures. The same seat cushion was used for all trials. The Oxford Pressure Monitor, a pneumatic cell device, was used to measure and record the interface pressures. Instrumentation for measuring and recording the surface shear force was constructed specifically for the study. Analysis consisted of statistically comparing changes in pressure values and shear forces derived from eight sitting postures with reference to values recorded in a defined neutral sitting posture. The pressure-distribution findings suggest that in the postures studied SCI subjects have maximum pressures that are higher than nondisabled subjects in all postures, ranging from 6% to 46% depending on the posture. Maximum pressures can be reduced by postural changes: forward flexion to 50°, -9%; backrest recline to 120°, -12%; and, full body tilt, -11%. On average, the SCI group members have peak pressure gradients (PPG) that are 1.5 to 2.5 greater than the nondisabled group. The maximum reduction in PPG occurred at backrest recline of 120°, -18%. Tangential shear force acts at the body-seat interface in all nine postures studied. Extrapolation of results suggests that full-body tilt to approximately 25° reduces the surface shear force to near zero. In contrast, a backrest-

only recline of 20° causes a 25% increase in the surface shear force. These results suggest that caution must be taken when using nondisabled subjects as surrogates for people with SCI because of the inherent differences between the groups. Also, researchers and clinicians should recognize that posture and body orientation in space are additional variables that can have a profound effect on the interaction between a seated person and his or her supporting surface.

Key words: *body-seat interface, pressure distribution, spinal cord injury, surface shear force.*

INTRODUCTION

Studies conducted over the past several decades have confirmed that the incidence and related costs of pressure-sore treatment remain a major health problem (1,2,3). Support of body weight while lying, sitting, or standing necessitates the transmission of internal stabilizing forces via the supporting tissues to external support surfaces. This results in tissue-distorting forces being transmitted to underlying soft tissues. Excessive or prolonged application of distorting mechanical forces can result in vascular occlusion, ischemia with eventual necrosis and the onset of a "pressure sore" (4,5). The onset usually occurs in the deeper tissues and then migrates toward the surface (6,7).

Both clinical and research evidence, although conflicting and inconclusive in several areas, are strongly biased toward excessive and/or prolonged application of surface pressure as being the predominant causative factors in pressure-sore formation.

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Although at least one investigator has questioned the primacy of pressure as a causal factor in pressure-sore formation (8), the fact remains that there is a dearth of research evidence suggesting any more dominant factor than interface pressure.

There is also compelling evidence that factors in addition to pressure are contributors and must also be considered when attempting to fully understand the pressure-sore phenomenon. Studies have implicated factors such as shear stress (9), impact loading of tissue (5), elevated temperature and humidity (10,11), age, nutritional status, general health, activity level (12), deformity, posture and postural change (13,14), body stature (15), and psychological deficits. Crenshaw and Vistnes (16), in their review of pressure sore research, effectively highlighted the studies and current thinking on the etiology and related factors that can predispose a person to pressure-sore formation.

Numerous research techniques and devices have been developed in an attempt to quantify the interface pressure. Mooney (17) described the design of a flexible polyvinylchloride (PVC) airtight pneumatic cell with follow-up clinical trials. Fernie (18) did an exhaustive analysis of the interface technology used before 1973. Ferguson-Pell (19) outlined the design criteria for an ideal interface-pressure-measurement transducer for measuring pressure differences across nonuniform surfaces. Garber and Krouskop (15) described the design and clinical use of a 12 × 12-matrix transducer device, commercially termed the Texas Interface Pressure Evaluator (TIPE). Bader (20) and Bader and Hawkins (21) reported on the development of the Oxford Pressure Monitoring (OPM) device that built on the previous work of investigators such as O'Leary and Lyddy (22), who first described the principle upon which the OPM is based.

The focus of research and clinical efforts with the cited measurement tools has been to quantify the interface pressure between a seated person and the supporting substructure, usually a seat cushion in a wheelchair. Efforts have been made to establish absolute threshold values above which seated persons are likely to be at risk of pressure-sore formation. Other applications have attempted to make comparisons between various supporting materials and related commercial products to guide improved product selection. Studies by Reddy *et al.* (23) and Guthrie (24) have emphasized the difficulty

in obtaining and accurately interpreting absolute pressure values, especially when used in nonplanar environments consisting of materials with compliance properties significantly different from human soft tissue. Reddy *et al.* (23) came to the conclusion that comparative values rather than absolute values are more likely to be meaningful, especially when the interface materials can be kept constant and the materials have mechanical properties approaching those of human buttock tissue.

Review of the research literature indicates that little attention has been given to the effects of posture and deformity on pressure distribution at the seat interface or to how those effects might vary between nondisabled and people with a spinal cord lesion. Zackarkow (14) strongly emphasized the importance of these factors and the need for research verification of clinical observations.

Over the years, both researchers and clinicians have indicated a concern about the effects of shear stress acting at the body-support interface. Guttman (25) emphasized the importance of distinguishing between purely vertical pressure and shear stress: "Shear stress is much more disastrous for it cuts off larger areas from their vascular supply." Reichel (26) expressed an opinion that raising the head of a hospital bed by even a few inches was capable of producing sufficient shear force over the sacral area to deprive large tissue areas of blood supply. Bennett *et al.* (9) came to the conclusion that combined pressure plus shear particularly promotes occlusion. The value of pressure necessary to produce occlusion can be nearly halved when accompanied by sufficient shear. Other investigators have also stressed that tissue deformation is a major etiological factor in ulcer formation (8,27,28). Chow and Odell (29) made the point that shear stress is involved in uniaxial pressure, localized pressure, and any nonuniform pressure distribution or pressure that causes tissue distortion.

In addition to shear stresses induced by the normal pressure, there are also shear stresses caused by forces that are acting tangential to the support surface, that is, friction forces. Very little progress has been made toward the measurement and use of frictional shear force information in clinical decision making (16). This is due, in part, to the complexity of the interface shear-stress phenomenon when viewed in its entirety. However, if one differentiates between the types of shear stresses, normally in-

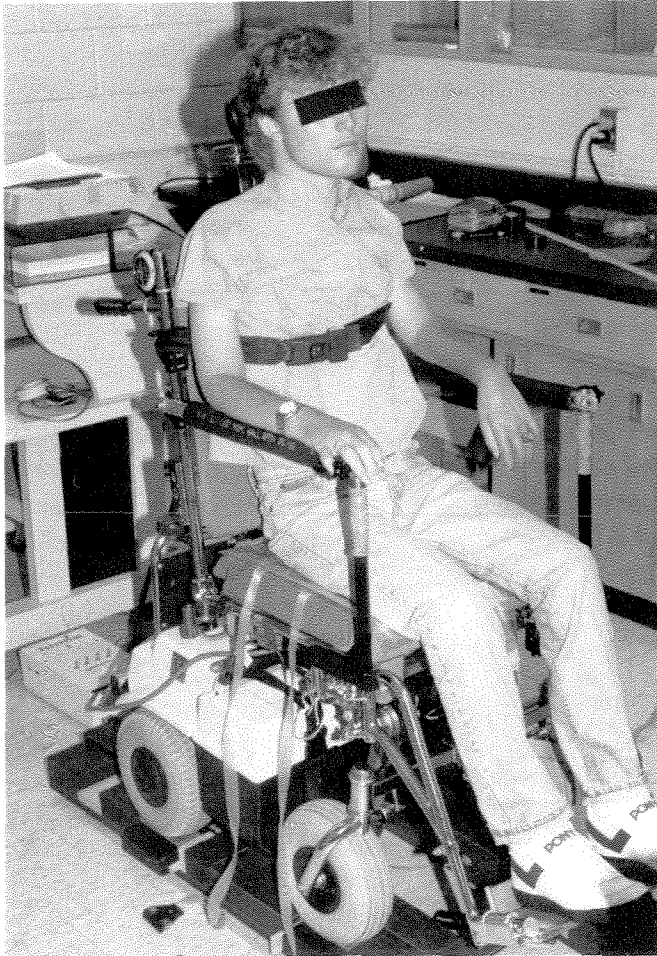


Figure 1. Disabled subject positioned on the BPC in neutral position (arms are placed on lap during pressure- and shear-recording sessions).

duced and tangentially induced, one can conceive of practical methods to measure the simpler tangentially induced shear (TIS) forces. Adoption of TIS measurements as a practical tool could provide clinicians with information about a variable, in addition to the pressure variable, that should be factored into clinical decision-making processes. However, it should be stated that the manner in which the shear- and normal-force components interact within the tissues will not be illuminated by this rather direct and simplistic approach.

In summary, this study has investigated the effects of changes in sitting postures and body orientation in space on interface pressure distribution and on TIS that acts at the body-seat interface.

OBJECTIVES

The objectives of this study were: 1) to identify pressure-distribution differences that may exist within and between the nondisabled and spinal cord injured (SCI) populations and to determine how the distributions may be affected as a result of deformity and/or alterations in sitting postures; and, 2) to investigate the manner in which TIS forces change with body posture, both within and between an SCI group and a nondisabled control group.

METHOD AND MATERIALS

Ten nondisabled and 12 SCI subjects participated in the study. The nondisabled group consisted of six males and four females with a mean age of 39.3 years and a range from 28 to 57 years. Mean body weight was 68.6 kg with a range of from 50 to 95.5 kg. All subjects in this group reported no previous impairments of spinal or pelvic movement.

All 12 SCI subjects were diagnosed as having complete lesions of their spinal cords for at least 5 years. The sample contained 10 males and 2 females: 7 paraplegic and 5 quadriplegic. Mean age was 40.9 years with a range of 25–66 years. Mean body weight was 59.8 kg with a range of 39–74.2 kg. The mean number of years since injury was 19.5 with a range of 6–54 years. In general, the subjects in the SCI group were all active individuals living in the community who regularly use a wheelchair.

Nine typical wheelchair sitting postures, as defined below, were studied. A specially designed body-positioning chair (BPC), using a Fortress model FS655 (Fortress, Inc.) with a powered recliner as the base, was used to obtain consistency of seated postures between subjects and between trials (**Figure 1**). The seat cushion used was constructed of three layers of 25-mm (1 in) Sunmate(b) foam (type, soft blue, 5 lb/ft³).

Two OPMs were used to measure the pressure values under the buttock area. Four, 3×4 cell-matrix transducers (48 cells) were fixed to the seat surface so that their positions relative to a reference axis would remain constant. The transducer array was placed so that the ischial tuberosities of all subjects would fall on the back two arrays (24 cells). The front two transducer arrays were used only to ensure that the maximum

