THE EFFECT OF PRECONDITIONING ON THE REPEATABILITY OF QUASI-LINEAR VISCOELASTIC PROPERTIES OF BUTTOCKS SOFT TISSUE

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ABSTRACT

A novel means of determining individuals susceptible to pressure ulcers is the development of biomechanical criterion specific to at risk tissue. The biomechanical evaluation of soft tissue necessitates the collection of repeatable measures. A method of obtaining these measures is preconditioning tissue before trials are performed. The effect of preconditioning on the repeatability of the quasi-linear viscoelastic model was evaluated in this investigation. The Computer Automated Seating System (CASS) was utilized to obtain soft-tissue data from subjects (force, pressure, tilt angle, tissue thickness, time). Analysis of this data showed that a more repeatable response occurs with tissue that has been preconditioned before testing.

BACKGROUND

Development of pressure ulcers on the buttocks of wheelchair users is a widespread problem. It has been found that between 50% to 80% of persons with spinal chord injuries will develop a pressure ulcer (1).

A way of exposing at risk individuals is to gain some knowledge of the differences in the biomechanical properties of the soft tissue of those who suffer from pressure ulcers and those who do not. A common method of modeling biomechanical properties of soft tissue is the use of Fung's quasi-linear viscoelastic (QLV) theory. The QLV theory has been found to be a viable method for determining the viscoelastic properties of ligaments and tendons (2,3).

The quasi-linear viscoelastic theory assumes that the stress relaxation function is dependent on both extension and time and can be expressed as:

$$s[e(t);t] = G(t) * s^{e}(e) \qquad G(0) = 1$$

Where σ^e is the "elastic response" (a function of strain only) and G(t) is the reduced relaxation function (a function of time). The stress at time t, $\sigma(t)$, is the convolution integral between the reduced relaxation function and the rate of elastic stress. With G(t) and $\sigma^e(\varepsilon)$ known, the entire stress history is described by the above convolution integral (3).

Previous experiments have shown that the internal structure of tissue changes with cyclic loading. After repeated cycling, a steady state is reached at which no further change will occur in tissue structure unless the cycling pattern is changed. In this preconditioned state, tissue has been found to exhibit more elastic stiffness and a reduced instantaneous viscoelastic response compared to tissue that has not been preconditioned (3,4). When tissue exhibits these properties it is said to be pseudo-elastic (3).

RESEARCH QUESTION

The goal of this investigation was to determine the effect of preconditioning on the stress relaxation response of buttocks soft tissue. Previous studies have shown that a repeatable stress relaxation response can be achieved after a cyclic preconditioning routine. This investigation makes

certain that the response of preconditioning of the buttocks soft tissue produces a repeatable response in the tissue, and that this response is similar to those previously documented for other tissues.

METHOD

Collection of Data

An able bodied subject was first seated on the CASS. The subject was positioned so that a CASS transducer was located 4 cm distal to his ischial tuberosity. This transducer was then elevated at a velocity of 1.058 mm/sec, held at a relative indentation of 20% of the bulk tissue for 300 seconds, and then unloaded at a velocity of 1.058 mm/sec. Data was collected throughout this period of loading. For trials not involving preconditioning this procedure was repeated three times.

For trials involving preconditioning the subject was first seated on the CASS as described above. However before the loading procedure was begun a preconditioning routine was performed. Preconditioning involved loading the tissue in a cyclic fashion for 12 cycles, alternating between 30% compression of bulk tissue and no compression (zero force). After preconditioning, the loading procedure was performed. This procedure was repeated three times.

Data Analysis

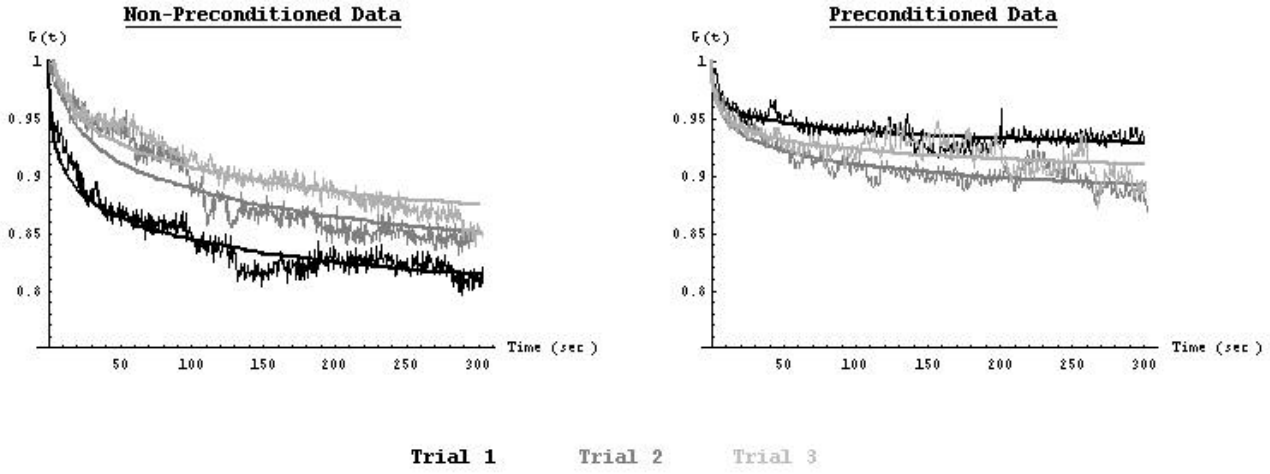
For this investigation G(t) was defined as follows, where γ is Euler's constant:

$$G(t) = \frac{1 - Cg - C\ln(\frac{t}{t_2})}{1 + C\ln(\frac{t_2}{t_1})}$$

τ_1 represents the instantaneous viscous phenomenon of the tissue, τ_2 represents the slow viscous phenomenon of the tissue, and C represents the reduction in amplitude of G(t). A linear regression was performed to determine the material constants τ_1, τ_2, and C. The percent relaxation of the tissue was also calculated.

The mean was determined for each parameter in each group (i.e. preconditioned group, non-preconditioned group). The mean values for each parameter were compared.

RESULTS



	Non-Preconditioned Data					Preconditioned Data				
	C	τ_1	τ_2	Percent Relaxation	R^2	C	τ_1	τ_2	Percent Relaxation	R^2
Trial 1	0.0315	0.6573	48.4585	18.2	0.86	0.0104	0.3890	81.9648	6.9	0.85
Trial 2	0.0371	7.01241	53.2858	14.4	0.79	0.0179	0.8118	68.1337	10.6	0.75
Trial 3	0.0315	7.7616	59.7413	12.1	0.81	0.0130	0.3262	74.8829	8.8	0.80
Mean	0.033	5.144	53.829	--	--	0.014	0.509	74.994	--	--

DISCUSSION

Noticeable differences were found amongst the parameters of the QLV model. A decrease in parameter C, the value governing reduction of the reduced relaxation function, was found between non-preconditioned and preconditioned tissues. This decrease corresponded to a lesser relaxation of the tissue. A decrease in the τ_1 parameter between non-preconditioned and preconditioned tissue was also exhibited, indicating a reduced effect of the instantaneous viscous phenomenon of the preconditioned tissue. An increase in the τ_2 value for preconditioned tissue was seen due to a greater influence of the slow viscous phenomenon of the tissue. Overall, preconditioning tissue resulted in a more repeatable tissue response and a smaller percent relaxation of the tissue. These characteristics were similar to those previously documented (3).

It should be noted that although no cyclic preconditioning procedure was performed for non-preconditioned tissue, it exhibited a preconditioned response after successive loading. The decrease in the percent relaxation after repeated loading can be attributed to an increase in elastic stiffness due to tissue deformation; in essence the successive loading of the tissue exhausted its instantaneous viscous response to deformation so that the response exhibited was one similar to an elastic solid. This phenomenon is described as pseudo-elasticity. Results of this investigation show that preconditioned buttocks soft tissue can exhibit pseudo-elastic behavior.

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ACKNOWLEDGEMENTS

This work was funded by a grant (#H133E990001) from the NIDRR Rehabilitation Engineering Research Center on Wheelchair Technology. Opinions expressed are those of the authors and not the NIDRR.

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