



Short communication

Entrapment of adult fingers between window glass and seal entry of a motor vehicle side door: An experimental study for investigation of the force at the subjective pain threshold

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ABSTRACT

In modern motor vehicles with automatic power windows, a potential hazard exists for jam events of fingers between the window glass and seal entry. This study determined entrapment forces acting on adult fingers at the subjective maximum pain threshold during entrapment in such windows.

The length and the girth of the proximal and distal interphalangeal joints of the triphalangeal fingers of the right hands of 109 participants (60 men, 49 women) were measured; the diameter was calculated from girth, which was assumed to be circular. The automatic power window system of a motor vehicle side door was changed to a mechanical system. During entrapment the force distributed across the four proximal interphalangeal joints (PIPs), and separately on the proximal interphalangeal (iPIP) and then the distal interphalangeal (iDIP) joints of the index finger was measured using a customized force sensor.

The maximum bearable entrapment force was 97.2 ± 51.8 N for the PIPs, 43.4 ± 19.9 N for the iPIP, and 36.9 ± 17.8 N for the iDIP. The positive correlation between finger diameter and maximum entrapment force was significant.

Particularly with regard to the risk to children's fingers, the 100 N statutory boundary value for closing force of electronic power windows should be reduced.

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1. Introduction

In modern motor vehicles with automatic power windows, a potential hazard exists in the form of finger-jamming events between the glass and seal entry. In January 2009, the U.S. National Highway Traffic Safety Administration reported around 2000 injuries and five fatalities caused by automatic power window systems (NHTSA, 2009). Since 1986, closing force restriction has been incorporated in power window designs. If an object is caught in the gap between the window glass and seal entry in the safety area between 4 and 200 mm, the closing of the window

is stopped immediately and the window is lowered. Window closing force also should not exceed the statutory limit of 100 N that is intended by various international guidelines to prevent strangulation and fatalities caused by asphyxia. However, this value is not based on any scientific investigations, nor does it account for the maximum forces bearable by the body parts that may be most at risk in motor vehicle power windows: fingers.

The aim of this study is to determine entrapment forces acting on adult fingers at the subjective maximum pain threshold during entrapment between the glass and seal entry of a motor vehicle side door window.

2. Methods and materials

A motor vehicle side door was installed in the lab and the electric motor was removed and replaced by a mechanical system. The closing and opening movement of the window pane was controlled by the participant with a foot pedal that was isolated in a clear plastic box and attached to the closing mechanism with a Bowden cable (Fig. 1). The return of the window to the starting position was

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