Predicting Neck Injuries Due to Head Supported Mass

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INTRODUCTION

In the past 30 years, technological advances in military equipment have resulted in more devices being mounted on the helmet to enhance the capability of the soldier. They include night vision goggles (NVGs), counterbalance weights, chemical masks, oxygen masks, information display visors, communications equipment, and more. As these systems are mounted to helmets, the soldier's neck must support this head-supported mass (HSM) and the resulting dynamic characteristics of the head and neck system are changed. It has been hypothesized that these systems increase the likelihood of both low and high-severity injury, but the additional risk of neck injury that these systems create has not been fully quantified before this study. Previous research has concluded that safe limits of head-supported device mass properties, such as mass location and distribution are important design criteria, the challenge being to establish those safe limits for HSM properties that can be tolerated by aviators (1). The purpose of this study is to quantify the effect of head supported mass on neck injury risk through computational modeling.

METHODS

The TNO MADYMO Detailed Neck model for a 50th percentile human male, presented by Van der Horst, was selected because it had been widely validated for a variety of loading scenarios, including six degree of freedom motion of individual spine segments, frontal, lateral, and rear impact tests, both from volunteer and cadaver testing (2).

A simulation test matrix was designed to vary the impact conditions and HSM properties added to the model. These parameters included seven impact directions, three impact magnitudes, nine mass locations, and three mass magnitudes (Figure 1). Using the last three variables a central composite faced design was created to optimize simulation time. Therefore, a total of 196 simulations were completed including 28 different configurations for each of the seven impact directions.

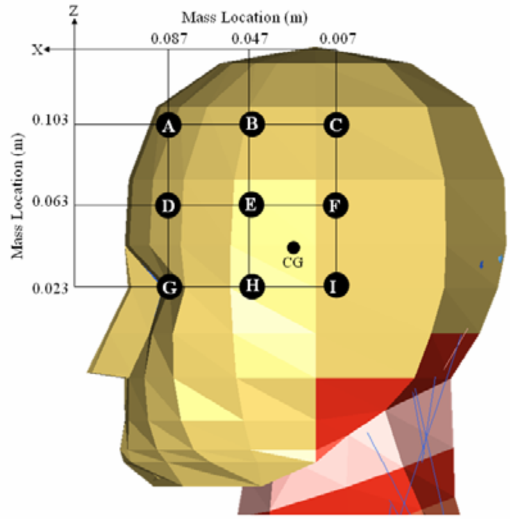

Figure 1: The locations for the HSM were chosen to be mostly above and in front of the head cg based on realistic equipment design.

The impact pulse for all simulations had the same shape, a half sine for 100 milliseconds, but the magnitude of the pulse varied between three different peak magnitudes for the central composite faced design. The low, medium, and high severity impacts were modeled with 5.0 g, 13.5 g, and 22.0 g acceleration peaks respectively. These pulse durations and magnitudes are used to represent a helicopter to ground impact. While HSM injuries occur in other circumstances, a low level long duration impact is a survivable one in which the neck injuries can be prevented based on the HSM design. The outputs of the model were set so Fx, Fz, and My were measured using the lower neck load cell between T1 and C7. The force and moment data from the simulations provided the necessary information to determine injury risk using a beam criterion (3).

RESULTS

The effect of pulse magnitude is more dominant in the directions that create a flexion or lateral bending moment. These directions are negative X, positive Y, XZ 60, YZ 45, and XY 45, which all have very similar peak risk values for each simulation configuration. For these five impact directions the average risk for the lowest pulse magnitude is 2.0% (±0.6%). The average level of risk increases to 11.8% (±5.4%) for the medium pulse magnitude. The highest level of risk is 70.0% (±4.6%) for a peak acceleration of 22.0 g. Note that this is not simply due to the added mass but the baseline risk increases for the higher pulse magnitudes as well.

The two directions not reported in the previous averages affect neck injury risk quite differently. The negative Z impulse direction has very low levels of injury risk for all pulse magnitudes. Because the main kinematic response from this impact direction is compression and not a flexion or lateral bending moment, the average risk for any HSM configuration is 3.3% (±2.4%) with the highest maximum risk equal to 14.0%. Conversely, the positive X impact direction induces an extension moment for all of the impact levels and HSM configurations. Therefore, the neck is in a weak position and the risk, even for baseline, is very high. The average risk associated with the peak beam criteria for these simulations is 93.8% (±9.4%) with the lowest risk equal to 70.9%. For both of these impact directions the contribution of HSM location or mass to the level of risk is not a dominating factor. The extremely high or low risk is primarily associated with the impact direction.

CONCLUSIONS

Adding HSM does increase the risk of neck injury, but the impact level the subject is exposed to is a more dominating factor in determining injury risk. The impact directions are critical in HSM evaluation because they determine the neck moment. For the highest acceleration the mass magnitude and location more drastically affect the level of risk associated with the HSM configuration than for the lower accelerations. All of these factors should be considered in designing HSM configurations for various applications.

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