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Ground Troop Helmet Electronic Cable Safety Design Issues (Reprint)

By

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Several development efforts are ongoing to integrate electronic devices onto ground soldier helmets which improve tactical advantages over adversarial forces. These devices often receive electrical signals and power from remote components located on the soldier. While technology is progressing to develop wireless systems to transfer these signals, basic wire technology appears to be the most secure and reliable at this time. These interface cables are tethered between the helmet and torso. These tethered cables introduce new injury risks to combat soldiers which must be addressed during system design.

The injury risk is derived from the possibility of catching or snagging the interface cable. Both cable ends are secured, one to the electronic device mounted on the wearer's head or helmet, and the other to some location on the soldier's torso. A snag of the interface cable would introduce loads to the wearer's head and torso which could be

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The likely injury loads are those applied to the head and neck structure. Human head and neck tolerance to external loadings are reviewed to establish guidelines for improved safety design. Consideration is given to the various loading conditions and injury mechanisms.

GROUND TROOP HELMET
ELECTRONIC CABLE SAFETY DESIGN ISSUES

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Abstract

Several development efforts are ongoing to integrate electronic devices onto ground soldier helmets which improve tactical advantages over adversarial forces. These devices often receive electrical signals and power from remote components located on the soldier. While technology is progressing to develop wireless systems to transfer these signals, basic wire technology appears to be the most secure and reliable at this time. These interface cables are tethered between the helmet and torso. These tethered cables introduce new injury risks to combat soldiers which must be addressed during system design.

The injury risk is derived from the possibility of catching or snagging the interface cable. Both cable ends are secured, one to the electronic device mounted on the wearer's head or helmet, and the other to some location on the soldier's torso. A snag of the interface cable would introduce loads to the wearer's head and torso which could be transferred to the neck structure. Even with a breakaway connector, it is possible for the connector body to be caught and apply injury producing loads to the wearer.

The likely injury loads are those applied to the head and neck structure. Human head and neck tolerance to external loadings are reviewed to establish guidelines for improved safety design. Consideration is given to the various loading conditions and injury mechanisms.

Introduction

The Land Warrior development program, managed by the Soldier Systems Command (SSCOM), provides combat troops with protective helmets configured with integrated electronics. This helmet configuration will utilize a conventional cable harness to provide electrical signals and power to the helmet mounted electronics. The hazard of inducing a neck injury to the wearer by cable snag has been identified.

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The U.S. Army Aeromedical Research Laboratory (USAARL) is providing technical support to the Land Warrior program by attending meetings and collaborating on issues pertaining to soldier head and neck injury (reference 1). During numerous meetings and telephone conversations, the topic of neck injury due to the helmet cable harness snag was discussed. USAARL agreed to research the topic and prepare a recommended position on cable loads for this application.

Background

As the soldier moves during maneuvers, it is expected that the helmet cable harness will become entangled with various objects such as vegetation, obstacles, or vehicle structures. Continued body motion after a helmet cable snag could produce high loads to the wearer's neck, inducing an injury. There are at least four possible approaches to reduce or eliminate this hazard: 1) remove the cables, 2) allow the helmet to separate from the wearer, 3) conceal the cables, and 4) allow the cable to separate under load. These options are discussed briefly below.

Approach 1 is to remove the cables. This would eliminate the neck injury risk due to cable snag. However, for this approach to be feasible and to meet the objectives of the Land Warrior program, technology must be readily available to incorporate a wireless communication and data transfer system between the helmet and processor unit. While this technology has been developed, it has not matured sufficiently to be fielded in military combat applications. The lack of a fieldable technology at this time makes this option unacceptable since it defeats an important goal of the Land Warrior program. This goal is to provide U.S. soldiers the tactical advantage offered by the helmet-mounted devices.

Approach 2 is to allow the helmet to dislodge. Allowing the helmet to dislodge from the wearer is not considered an acceptable option since the infantry helmet provides impact and ballistic protection. It is believed that the likelihood of receiving a head impact after helmet loss is greater than the likelihood of receiving a neck injury due to a cable snag. Allowing helmet removal to occur would increase the Army infantry soldier's risk of head injury to undesirable levels.

Approach 3 is to conceal the cables. Concealing the cables will reduce, but not eliminate, the risk of inducing a neck injury. Efforts should be made to reduce the cable projection distance and exposure lengths. The wire projection distance (the distance between the wire and nearest body region) must be minimized regardless of the viewing perspective. There is a trade between wire length and projection distance. The challenge is to optimize the system such that the snag potential is minimal. The snag potential can be assumed to be directly proportional to the area of projection created by the cable routing. Ideally, the cable projection area is minimal when the cable runs along the side of the neck. In this case, the object which could snag the cable is also likely to be in contact with the neck. A concern with the cable routing along the neck is user acceptability and head mobility.

Approach 4 is to allow the cable to separate under load. This approach reduces the possibility of a neck injury, but does not eliminate it. Cables and connectors can be designed to breakaway (or separate) at loads below a general threshold; however, human tolerance variability and the potential for unpredictable load vectors prevent the injury risk from being eliminated.

Discussion

The purpose for this assessment is to provide rationale for a maximum cable tensile force for the Land Warrior helmet system. This is predicated on the selection of the fourth approach listed above to mitigate the risk of neck injury by a helmet cable snag. Determination of the allowable cable tensile force is based on neck tolerance to external loadings and the loading mechanism.

Head motion

Voluntary head motions are typically described by the four rotations illustrated in reference 2, Figure 1. Flexion is the forward bending where the chin is likely to contact the chest. Extension is the rearward bending where the back of the head is likely to contact the upper shoulders. Lateral bending may be directed to the left or right and is characterized as trying to place one's ear onto the shoulder. Axial rotation is the turning from side-to-side in a "no" gesture. Head translation is usually experienced during an individual's conscious effort to induce a translation motion. However, a dynamic loading can create head translational and rotational motions.

Neck injury and tolerance

Neck injury occurs when the head motion exceeds voluntary limits. When the head is placed at a voluntary limit, the addition of small motion or external force in a direction other than the restoring direction may produce injury. From an engineering mechanic's perspective, each cervical vertebral body can be expected to experience bending moments, compression, tension, torque, and shear as illustrated in reference 3, Figure 2 . Excessive loading in any of these engineering descriptors can cause injury. Significant effort has been expended to understand cervical injury mechanisms and injury thresholds as evidenced by the available literature on the topic. This literature includes review articles which discuss the many efforts and findings (references 3, 4, 5, and 6).

An important part of this position paper is to recommend a desirable level of protection against neck injury. The consequence of neck injury can vary in symptoms from fatal or paralysis to minor soreness. It should be obvious that protection is desired from injuries which could cause a fatality or paralysis. Minor superficial neck injuries such as cuts, abrasions, and contusions usually do not affect individual soldier performance as long as proper dressing and antibacterial medications are applied, as necessary. However, soft tissue injuries such as strains and sprains, while considered minor in a noncombat environment, could affect soldier performance. Typical acute neck strain symptoms include: neck stiffness, headache, neck pain, dizziness, nausea, double vision, impaired concentration, impaired memory, irritability, weakness, and others (reference 7). It is arguable that soldiers experiencing any one of these symptoms would not be expected to complete a mission as efficiently or effectively as they would if they did not experience the symptom. Thus, it is recommended that any helmet cable induced neck injury not be allowed to exceed a treatment level greater than first-aid.

For the intended application, the recommended injury thresholds are those for the onset of soft tissue injuries. These include neck sprains and strains that could degrade a soldier's performance during a military operation. These thresholds are generally interpreted as the voluntary limits before initiation of pain. Summarizing the data reviews by McElhaney and Armenia-Cope (references 3 and 8), the neck injury tolerance is reproduced in Table 1.

Table 1. Neck injury tolerance.

Loading mechanism	Moment tolerance (ft-lbs)
Extension	35
Flexion	44
Axial Torsion	9
Lateral Bending	29

The thresholds listed in Table 1 appear to be low when considering the weights used by athletes during weight training and neck exercise. During neck exercise, the participant is within the normal range of motion and the neck muscles are applying sufficient force to lift various weights. These reported neck injury tolerance values in Table 1 are based on the neck being at its motion limitation with an additional load being applied to force the neck beyond its normal motion range.

These values are not gender or physical fitness specific. This is an obvious lack in the knowledge of injury tolerances. However, the presented values can be used to determine the maximum desired cable breakaway tensile loads by considering the distance between the load application point and the anatomical head and neck pivot point, the occipital condyles.

Helmet loading

Assuming that a cable snag will occur, it is useful to consider how the loads will be transmitted through the head and helmet to the neck. Relative to the torso, external loadings to the helmeted head are conceivable in most any direction. For example, five basic loading directions are provided in Table 2 with their provoking activity.

Table 2. Potential helmet loading directions and operational activity.

Loading direction	Operational activity
Upward	rappel, jumping off structures or obstacles
Downward	climbing obstacles and cliffs, crawling through vegetation or obstacles
Rearward	forward movement through vegetation or obstacles
Forward	rearward movement through vegetation or obstacles
Lateral	lateral movement through vegetation or obstacles

Cable attachment onto the helmet becomes a factor when considering the head and neck loading mechanics. The critical variable is the distance between the cable attachment point and the head and neck pivot point, the occipital condyles. This distance creates a moment arm for a torque to be applied about the pivot point. Inspection of a personnel armor system for ground troops (PASGT) helmet reveals the maximum distance from the shell lower edge to the occipital condyles to be approximately 6 inches. This 6-inch distance is used as the moment arm length.

Cable tension limits

Limits for cable tension can be calculated by considering the neck injury tolerance and cable mounting position (moment arm) on the helmet. Moments are defined as a force (F) applied at a distance (d) away from a pivot point: M=Fd. This simple equation can be rearranged to solve for the force value as: F=M/d. The moment arm, 6 inches, is used for all loading directions. The moment values are based on the selected human neck injury tolerance presented in Table 1. By selecting the smallest injury tolerance value, 9 foot-pounds for axial rotation, the maximum allowable cable force can be calculated. By substituting d=6 inches and M=9 foot-pounds, into the above equation and solving for force results in a value of F=18 pounds. Thus, the cable running between the helmet and torso should be designed to fail at a cable tensile load of 18 pounds. This should minimize the risk of inducing a neck injury as a result of a helmet cable snag.

This 18-pound limit can be adjusted by changing the moment arm distance created by the cable attachment point on the helmet. A greater moment arm distance will result in lower allowable forces. Shorter moment arms result in increased allowable forces. Also, as other relevant neck injury data is established, new calculations could result in different force requirements.

Conclusions and recommendations

1. There is a potential for a cable, routed between the soldier's helmet and torso, to snag or become entangled in Army combat environments.

2. Combat soldier neck injury resulting from helmet cable snag should not exceed the first-aid level of treatment. A more serious injury may result in degradation of combat effectiveness.

3. The helmet cable should be routed close to the neck to minimize its projection area, thereby reducing the risk of cable snag and entanglement.

4. To minimize the risk of inducing a neck injury to combat soldiers, helmet cables should be designed to not transfer loads in excess of 18 pounds.

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<u>Bibliography</u>

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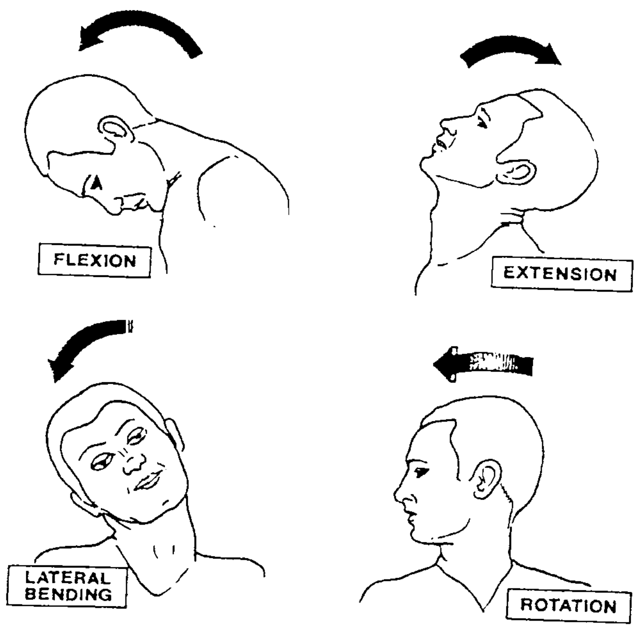

Figure 1. Head motion description.

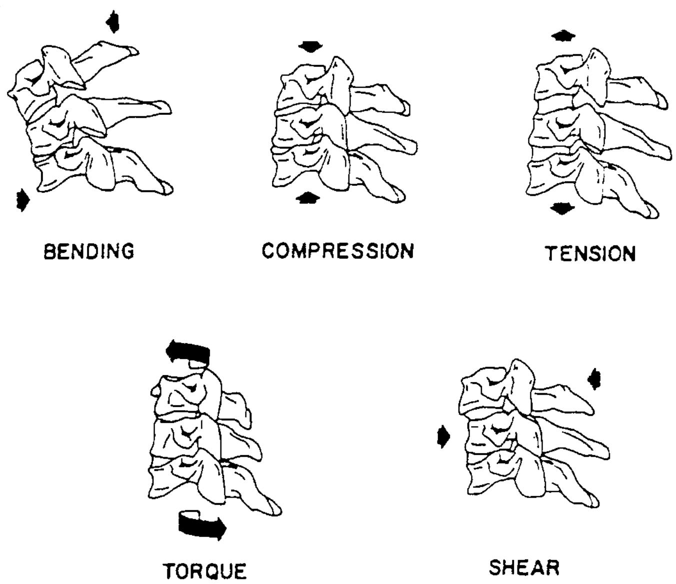

Figure 2. Neck injury mechanics.