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INTRODUCTION
Whiplash distortions of the cervical spine, occurring during the retraction phase of a rear end automobile accident, are known to cause posterior translation of the head relative to the chest and shoulders [1,2]. This anteroposterior shear produces sagittal plane rotation of the cervical spine which results in relative flexion between the occiput and the atlas (Fig. 1). This study demonstrates that there is a significant difference between the average angles of the anterior aspects and the posterior aspects of the superior facets of the atlas with respect to a horizontal (transverse) plane at $P<0.01$. We hypothesize that developmental variations in some individuals will allow excessive posterior translation of the head during rear end automobile accidents, and that this excessive motion may increase the risk of sustaining a whiplash-type injury for some individuals.

MATERIALS AND METHODS
In 20 fresh spine specimens, 3 metal markers were implanted on the cranium (1 on the inion, and 1 each on the left and right mastoid processes) and 3 metal markers were implanted on the atlas (1 on the anterior tubercle and 1 each on the left and right transverse processes) [3]. After digitizing the locations of these 6 metal markers relative to a global reference system, the atlas was separated from the cranium. The locations of the 3 metal markers on the atlas, along with additional bony landmarks (Fig. 2), were then digitized relative to a local axis system. The location of these additional landmarks, relative to the global reference system, was then calculated by mathematical transformation of the complete data set. The orientations of the anterior (LA$\rightarrow$LL$\rightarrow$LM$\rightarrow$LA) and posterior (LL$\rightarrow$LP$\rightarrow$LM$\rightarrow$LL) aspects of the superior articular facets of the atlas were then calculated relative to a transverse (horizontal) plane defined to pass through the left and right mastoid processes and the inion. The orientation of the anterior and posterior aspects were also calculated relative to a sagittal (vertical) plane defined to be orthogonal to the transverse plane while passing through both the inion and the origin of a local axis system.
RESULTS

The average angle of the left and right anterior aspects of the facets with respect to the transverse plane was found to be equal to 40.8 ± 13.1 degrees. The average angle of the left and right posterior aspects of the facets with respect to the transverse plane was found to be equal to 28.3 ± 10.3 degrees (Fig 3). There was a statistically significant difference between these two groups for P<0.01. The power of the test for alpha = 0.05 was equal to 0.893.

The average angle of the left and right anterior aspects of the facets with respect to the sagittal plane was found to be equal to 62.4 ± 11.3 degrees. The average angle of the left and right posterior aspects of the facets with respect to the sagittal plane was found to be equal to 68.8 ± 12.4 degrees (Fig 3). There was not a statistically significant difference between these two groups for P<0.1.

DISCUSSION

Occipitoatlantal (OA) joint stability is dependent upon both soft tissue and bony structures. At birth the superior facets of the atlas are horizontally oriented [4]. They gradually assume the characteristic concave shape by 6 years of age [5], during which the stability of the OA joint increases. We hypothesize that developmental variations that reduce the angle of the posterior aspects of the superior facets of the atlas may allow excessive anteroposterior translation of the head during a whiplash-type accident. Some whiplash patients develop chronic head and neck pain that is accompanied by atrophic changes in suboccipital musculature, most significantly the rectus capitis posterior minor (RCPMi) muscles [6]. Atrophy of these muscles has not been seen in either female control subjects [7] or patients with chronic, insidious-onset pain [8]. Our model of the OA joint suggests that RCPMi muscles are at risk for an injury at the musculotendinous junction (tendon tear) due to high levels of strain caused by eccentric lengthening during the retraction phase of a rear end automobile accident (Fig. 4), and that the atrophy may be evidence of this soft tissue injury, but not the cause of the chronic pain.

CONCLUSIONS

Our results suggest that the orientation of the superior facets of the atlas may make the OA joint less stable in response to anteroposterior shear forces than it is for lateral and posteroanterior shear forces.

REFERENCES