Risk of cervical injuries in mixed martial arts

T Kochhar, D L Back, B Mann, J Skinner

Background: Mixed martial arts have rapidly succeeded boxing as the world’s most popular full contact sport, and the incidence of injury is recognised to be high.

Objective: To assess qualitatively and quantitatively the potential risk for participants to sustain cervical spine and associated soft tissue injuries.

Methods: Four commonly performed manoeuvres with possible risks to the cervical spine were analysed with respect to their kinematics, and biomechanical models were constructed.

Results: Motion analysis of two manoeuvres revealed strong correlations with rear end motor vehicle impact injuries, and kinematics of the remaining two suggested a strong risk of injury. Mathematical models of the biomechanics showed that the forces involved are of the same order as those involved in whiplash injuries and of the same magnitude as compression injuries of the cervical spine.

Conclusions: This study shows that there is a significant risk of whiplash injuries in this sport, and there are no safety regulations to address these concerns.

Materials and Methods

The motion during the techniques was recorded by two Sony (DV470 and 478T) digital video camcorders, one filming the general motion of the fighter and the opponent, and one focusing on the cervical region as the opponent hit the floor. The cameras took images at a frequency of 40 and 50 frames/second. The motion of the head and neck was then qualitatively assessed.

Two experienced practicing martial artists took part in the video analysis. The fighter (performing the takedowns) was 33 years old, 170 cm tall, and weighed 80 kg. The opponent (being taken down) was 27 years old, 180 cm tall, and weighed 93 kg.
Each technique was performed a total of 10 times, each after a period of rest. This was for three main reasons. The first was to confirm that the kinematics of each manoeuvre was similar in each video analysis. The second was to measure the height from which the opponent was driven down on to the ground; an average height was taken. These measurements were calculated by analysing the film and marking reference points on the video stills of the height to which the opponent’s centre of gravity was raised. Reference marks were placed on the opponent’s anterior superior iliac spine, on the side of the fighter’s clothing, and on the wall on the other side from which the reference filming was taken. The centre of gravity was assumed to be slightly superior to the coordinate reference origin, namely at the level of the anterior superior iliac spine of the pelvis (but in the coronal and sagittal midline). The point of initial impact was also assessed from the video footage and noted. Finally, the position of the head, relative to the thorax, at impact and the end of motion was measured. This was done by comparing the video stills with standardised pictures, taken before the experiment, on a computer.

The third was to measure the time taken from the top of the takedown, when the fighter began driving the opponent down, to the point of impact; an average time was taken. This measurement was calculated using a digital stopwatch and the video footage, with the knowledge of the frequency of image capture of the camera.

These values were taken to construct mathematical models to help to correlate the manoeuvres with the biomechanical information present in the current literature.

RESULTS
Kinematic analysis of the four manoeuvres
O goshi: the hip throw
The fighter’s body was raised and driven down on to the ground from an average height of 115 cm. The average time for the takedown was 0.29 second.

From the video, the first point of impact was at T2/T3 in the midline (9/10 manoeuvres.) At the point of impact, the cervical region was slightly flexed, with the head in forward translation of a mean of 4–5 cm (when compared with standard reference pictures of the fighter’s resting positions). On impact, the body came to rest rapidly, but the unrestrained head and neck were still subject to the driving acceleration. The head then moved backwards with associated cervical hyperextension, until the occiput impacted on the ground. Mean posterior translation was 6.2 cm, from its resting position, before the occiput hit the ground. There was then a forward motion of the head with cervical spine flexion. The impact finished with the head in the starting position of anterior translation of about 4–5 cm.

The motion from impact to rest of the head and the cervical region suggests forced displacement of the head until it hits the ground and then forward flexion until rest.

The suplex
Problems were encountered in the video analysis of this manoeuvre. During the practice run, the opponent sustained an injury to his anterior cervical region and was unable to proceed. No other volunteer was happy to participate in the suplex, not even the first author! Analysis of this manoeuvre was abandoned.

The opponent was cleared of any serious cervical injury by his regular practitioner and had fully recovered within a week.

The video analysis taken from the single run through of this manoeuvre revealed a height of 155 cm. The time taken from the initiation of driving the opponent down to impact was 0.32 second. From the video analysis it can be seen that the initial point of impact was the mandibular symphseal region. There was then continued and sustained posterior translation of the head with associated cervical hyperextension until the end when the opponent came to rest and began to complain of pain. A significant part of this hyperextension seemed to be from the atlanto-occipital segment.

The posterior translation of the head was measured at about 9 cm. Surprisingly there was no axial rotation—that is, the opponent did not twist his head away from the full frontal impact upon the ground.

Although this part of the experiment was not completed, it proved enlightening and informative to all participants.

The souplesse
The mean height from which the opponent’s assumed centre of gravity was 142 cm. The mean time taken for this part of the manoeuvre was 0.31 second.

The initial point of impact was the T2/T3 region, (8/10) in the midline. The head was measured at a position of positive anterior translation of 4 cm. Once the thorax and body came to rest on impact, the unrestrained head once again moved back with associated cervical hyperextension until the occiput hit the ground, the head being displaced 6.7 cm behind its resting position.

From this impact of the head, the head moved anteriorly, beyond its starting position, but within normal limits of

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movement—that is, the chin did not touch the anterior chest wall. This motion was very fast, and we were unable to collect valid measurements because of the limitations of our equipment. The impact finished with the head coming to rest in the neutral position.

The guillotine drop

The fighter began to drive the opponent down from an average height of 110 cm. This was not a throw, and so the opponent’s total body weight was not involved. The time taken to drive the opponent down had a mean value of 0.41 second. It proved to be difficult to analyse the video. This was due to the nature of the manoeuvre, in that the choke hold of the fighter masked the neck movements. However, it seems that the choke forces the opponent into a position where the neck is flexed. As the opponent falls to the ground, flexion is increased, with a probable increase at the atlanto-occipital motion segment. The initial point of impact seemed to be at the level of the xiphisternum (T9). As the fighter drives back, the opponent’s neck is flexed forward once again in a rapid fashion (the video imaging was too slow to calculate this time). It seems that this manoeuvre causes strong flexion forces on the cervical spine and its junction with the occiput.

Values were calculated and compared with those found in the literature for scenarios with similar kinematics and known associated cervical injuries. For these calculations some assumptions were made:

- The centre of gravity was positioned at the level of the anterior superior iliac spines, midline in coronal and sagittal planes.
- There was a constant driving acceleration. This is in keeping with the description of the classical technique in each manoeuvre.
- The motion and forces acted in the same sagittal plane from initiation to impact of the manoeuvre.
- The neck flexors have sufficient reaction time to resist the posterior translation of the head. The literature suggests that in rear end impacts, the sternocleidomastoid muscles cannot react quick enough to oppose the hyperextension (reaction time is quoted as being 100–150 milliseconds), and once in hyperextension they have minimal power.
- The weight of the opponent’s head was 6.5 kg and the weight of the neck made no contribution to the driving force of the head after impact. This value was calculated as 6.95% of the total body weight as suggested in the literature.

It should also be noted that the mathematical models have been constructed with a view to posterior linear motion of the head. Clearly, the motion of the functional spinal units (and thus the general motion of the cervical spine) involves angular motion. The motion of the head-neck complex receives a significant contribution from the atlanto-axial complex in the way of angular motion in the sagittal plane. However, most studies have presented their results with respect to the linear motion of the head. For our study to be comparable with the published literature, the authors have constructed the experiment and models in a similar fashion.

Mathematical models

To assess the biomechanical forces, we need to find the acceleration from the fighter driving the opponent to the ground. From the equation

\[ S = ut + \frac{1}{2}at^2 \]

for the manoeuvre

where \( S \) is the distance of the opponent’s centre of gravity before being driven down to the ground, \( t \) is the time for the opponent to be driven to the ground, \( a \) is the driving acceleration, and \( u \) is the initial velocity (for this scenario it is equal to zero), we can calculate the force of the impact on the opponent’s upper back.

Using Newton’s second law of motion and assuming a constant acceleration throughout the fall,

\[ F = ma \]

where \( F \) is the driving force of the impact on the opponent as he lands (N) and \( m \) is the mass of the opponent (kg), and assuming that the opponent’s head weighs 6.53 kg, we can calculate the driving force of the head backwards after impact.

The other value required is the transfer of energy from the opponent being driven into the ground. When the opponent is at the top of the manoeuvre, before he falls to the mat, he has potential energy. The equation for potential energy measured in joules (PE) is as follows:

\[ PE = mgh \]

where \( h \) is the distance of travel—that is, from the top of the manoeuvre to impact (cm).

By using the motion equation

\[ v^2 = u^2 + 2as \]

we can calculate the velocity of the body at impact (\( v \) is the final velocity at impact).

Table 2 summarises the results.

Comparison of manoeuvres with evidence from the literature

To confirm or reject the possibility of cervical injury, these variables were compared with similar incidences from the published literature shown to produce cervical neck injuries.\(^{10-14}\)

The kinematics of the o goshi and souplesse from the point of impact bear a considerable resemblance to the kinematics of a rear end motor vehicle collision. With respect to car collisions, it has been shown that the biomechanics, kinetics, and kinematics all contribute towards the outcome. It can be seen that the impact with the opponent on the ground can be directly correlated with the moment of impact in a rear end collision. If one compares the force imparted on the driver from the seat with the reaction force of the ground on the opponent, one can see that they act at similar sites and in similar directions. There is also similar posterior translation of the head after impact in both our studied manoeuvres and the car impact models. We cannot prove from this study that the cervical motion after impact in the o goshi and souplesse has the biphasic S shaped kinematics as described by Panjabi et al.\(^{16}\) However, the action of the force causing this motion is of similar magnitude in the two scenarios and the gross pattern of motion is comparable.

The authors strongly believe that, as the gross kinematics and action of the driving forces are comparable in these scenarios to the biphasic whiplash motion scenario, then injury will similarly occur in martial arts. As the magnitude of the force is of the same order, we conclude that it is likely that the biphasic motion of whiplash does occur in the hip throw and souplesse after impact of the body.

We calculated the kinetic energy (KE) created by the impact for these two manoeuvres:

\[ KE = \frac{1}{2}mv^2 \]

We find that the kinetic energy imparted to the subjects was

\[ KE_{o goshi} = \frac{1}{2} \times 450 \times (2)^2 = 900 \text{ J} \]

\[ KE_{s o u p l e s s e} = \frac{1}{2} \times 94 \times (9.2)^2 = 3978 \text{ J} \]

This shows that the kinetic energy associated with these manoeuvres exceeds the threshold limit to create whiplash motion. If the statement that energy transmission plays a role
injury, this comparison supports the theory that the
manoeuvres reproduce the motion and have a significant risk
of injury. However, the role that energy transmission plays in
injury has not been assessed in the literature reviewed. With
respect to the two other manoeuvres (suplex and guillotine
drop), no studies were found in the literature with which to
compare the kinetics.

CONCLUSIONS

These four common mixed martial arts manoeuvres have
kinematics that can result in serious cervical injury.10–14 44
Strong parallels can be drawn between the kinematics
of rear end motor vehicle impacts and the described motion of
the o goshis and souplses.10–14 44 The gross motion of the
head-neck complex in these two manoeuvres and rear end
motor vehicle impacts is similar, including the mechanical
obstruction from hyperextension of the cervical region by the
floor and the car seat headrest respectively. The suplex
exhibits significant risk of hyperextension injury. The
guillotine drop kinematics reflect mechanisms of cervical
neck flexion injuries. It should be noted that enactment of
the correctly applied suplex in our experiment did result in
cervical injury, albeit mild.

Comparison of our biomechanical models with road trauma
research has revealed comparable forces to produce
cervical injury.10–14 44 It should be noted that we have studied
the performance of classical movements by experienced
practitioners. These are not the movements that a less
experienced practitioner would consistently produce, and
deviations may produce even larger forces.

This study has clearly shown that there is a risk of cervical
injury from these four manoeuvres used in martial arts.

What this study adds

This study shows clear similarities in the force, kinematics,
and biomechanics required to produce cervical neck injuries
in rear impact vehicle accidents and these four common
martial arts manoeuvres. It shows that significant forces are
applied to this region, and injuries may be more severe than
realised.

What is already known on this topic

There is minimal information in the literature documenting the
mechanisms of cervical neck injuries in martial arts. The
mechanisms of the injuries and forces required have not been
clearly analysed, yet the potential for major severely
disabling injury is present.

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