

Effects of DeRoyal Universal XTW Cervical Collar on Head-Cervical Movements in Comparison with Miami J Advanced and Aspen Vista® TX Collars

Biomechanics/Sports Medicine Laboratory
Department of Exercise, Sport and Leisure Studies
The University of Tennessee
Knoxville, TN, USA



A research report prepared

By

Songning Zhang, PhD

Jacob Gardner, MS

Xuan Liu, BS

Contact –

Songning Zhang, PhD and FACSM

Director, Biomechanics/Sports Medicine Laboratory

Department of Kinesiology, Recreation, & Sport Studies

The University of Tennessee

Knoxville, TN, USA

Phone: (865) 974-4716

FAX: (865) 974-8981

Email: szhang@utk.edu

EXECUTIVE SUMMARY

The main objective for the research project was to examine the kinematic restrictive effects of a newly designed adjustable cervical collar (Universal XTW, DeRoyal Industries, Inc.) on the head-cervical 3D movements compared to those of two other similar cervical collars, Aspen® Vista® TX and Miami J® Advanced. A total of 19 subjects (9 females and 10 males) participated in the study. During testing, each subject performed 5 movement trials to the beat of a metronome set at 50 beats per minute in each of the 12 testing conditions, which is the combination of 4 collar conditions, no collar and 3 cervical collars, and 3 movements, flexion-extension, left-right lateral flexion and left-right axial rotation. Three-dimensional kinematic data of the head, cervical collar and trunk were captured using a 9-camera Vicon motion capture system at 240 Hz. The statistical comparisons showed that the maximum extension angle was reduced in the XTW compared to Vista® TX ($p = 0.011$). In addition, the total ROM was reduced in both Advanced ($p = 0.043$) and XTW ($p = 0.042$) compared to Vista® TX. The maximum left flexion angle was also decreased in Advanced ($p = 0.002$) and XTW ($p < 0.001$) compared to Vista® TX. Similarly, the maximum right flexion angle and total ROM were also decreased in Advanced ($p < 0.001$ & $p < 0.001$) and XTW ($p < 0.001$ & $p < 0.001$) compared to Vista® TX. The maximum left and right axial rotation angles and total ROM were all reduced significantly in the three collars ($p < 0.001$) compared to no collar. In addition, the maximum right rotation and total axial rotation ROM were reduced in XTW ($p = 0.005$ & $p = 0.005$) compared to Advanced. The peak left axial rotation angle was decreased in XTW ($p = 0.031$) compared to Vista® TX. In conclusion, the study results demonstrated that both Universal XTW and Miami J Advanced cervical collars had greater effects on restricting head-neck movements in flexion-extension and lateral flexion. However, the Universal XTW collar showed greater restriction on axial rotations of head-neck than Miami J Advanced and Aspen Vista® TX collars. No apparent effects of the adjustable support structure were observed on the head distractions for all three tested cervical collars.

INTRODUCTION

Cervical collars are often prescribed to patients who have sustained a cervical spine injury. The objectives for spinal orthoses applications include correction of spinal deformity and malalignment, intervertebral segmental immobilization, regional stabilization, maintaining a specific spinal posture, and protection from damaging stresses during the healing process(White & Panjabi, 1990). The cervical spine enjoys the greatest range of motion (ROM) of the entire spine. Cervical orthoses are often prescribed to be used in both extrication stabilization of trauma patients and as a treatment option of injuries to the cervical spine (Richter, et al., 2001).

There are three types of conventional cervical braces with variation within each category, including soft cervical collar, upright poster-brace with padded mandibular and occipital supports, and cervicothoracicorthoses with support similar to the poster brace but further reinforced by rigid metal or plastic connections(Johnson, Hart, Simmons, Ramsby, & Southwick, 1977; White & Panjabi, 1990). More recently, adjustable cervical collars have emerged in the market and offer better fit and superior supports and restrictions of head-neck motions.

Therefore, the objective for the research project was to examine the kinematic restrictive effects of a newly designed and adjustable cervical collar (Universal XTW, DeRoyal Industries, Inc.) on the head-cervical three-dimensional (3D) movements compared to those of two other similar cervical collars, Aspen® Vista® TX and Miami J® Advanced.

METHODS

Participants

A total of twenty subjects were recruited and participated in the study. Due to technical difficulties, one subject was excluded in the final analyses. Therefore, 19 healthy female (N=9,

Age: 28.4 ± 6.8 years, Height: 1.66 ± 0.02 m, Mass: 62.5 ± 13.0 kg, BMI: 22.6 ± 4.3 kg/m²) and male (N=10, Age: 27.1 ± 3.9 years, Height: 1.78 ± 0.08 m, Mass: 74.7 ± 13.9 kg, BMI: 23.6 ± 3.3 kg/m²) subjects between the ages of 18 and 40 were included for the analyses. Subjects were free of injury at the time of testing and had no major past head, neck, or trunk injuries or pathologies. Prior to participation, all subjects read and signed the study's informed consent which was approved by the University of Tennessee Institutional Review Board.

Instrumentation

3D High-speed Video System: A nine-camera motion capture system (240 Hz, Vicon Motion Analysis Inc., UK) was used to obtain the three-dimensional (3D) kinematics during the test. Reflective anatomical markers were placed on the greater trochanters, acromion processes, and ear canals. A cluster of four reflective markers affixed to a semi-rigid thermoplastic shell was placed on the trunk to track the trunk motions. Four tracking markers were placed on a headband affixed around the head to track head motions (Figure 1). Eight additional markers were placed on the cervical collars to identify and track the collar movements during the dynamic testing. Separate static trials were recorded for each of the four collar conditions.

Customized testing chair: Subjects were asked to sit in a customized testing chair equipped with two shoulder straps, a waist strap and a lap strap. The trunk and waist of subjects was stabilized in the chair by the respective straps while the neck and head were free from any restriction.

Visual3D: Visual3D (C-Motion, Inc.) 3D biomechanical analysis software suite was used to compute 3D kinematic variables. The 3D marker trajectories were filtered at 4 Hz using a low-pass zero lag digital Butterworth filter.

Customized software: Customized software (VB_V3D and VB_Tables, Microsoft Visual BASIC, 6.0) were used to compute and determine critical events of the computed variables from the Visual3D outputs, and to organize the data for reports and statistical analyses.

Cervical collars (Figure 2): Adjustable cervical collars, Aspen® Vista® TX Collar (Aspen

Medical Products, Irvine, CA), Miami J® Advanced (Ossur Americas, Foothill Ranch, CA), and Universal XTW (DeRoyal Industries, Inc., Powell, TN) were applied to the neck and trunk regions during the experimental conditions according to the manufacturer's instructions.

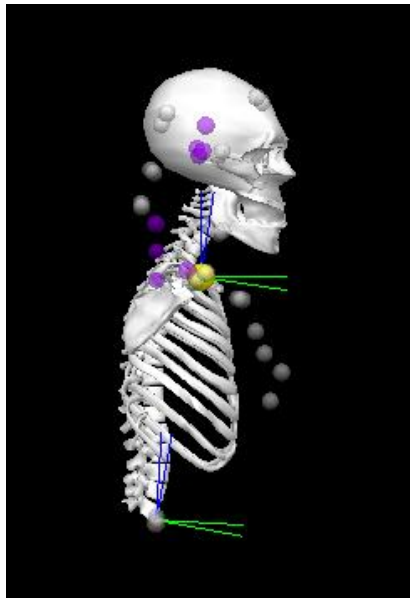


Figure 1. The 3D models of the head-neck, trunk and cervical collar (invisible from the view).



A)



B)



C)

Figure 2. Cervical collars tested in this study: (A) Aspen® Vista® TX Collar, (B) Miami J® Advanced, and (C) DeRoyal Universal XTW.

Experimental Protocol

After reading and signing the informed consent form, subjects were instructed to lie in a supine position on a treatment table where the cervical collars were applied as per the manufacturer's instructions. Once the collar was applied, the head height was adjusted for each collar so that the subject's head remained in a neutral position while sitting/standing. There were four collar conditions which were no collar (control), Vista® TX, Advanced, and XTW, and three movement conditions of flexion/extension, left and right lateral flexion and left/right rotations for a total of 12 testing conditions.

Following the collar application, reflective anatomical and tracking markers were placed on the subject's body and on the cervical collars as described above. The markers were recorded using 3D motion analysis software (Vicon Nexus) in order to quantify the three motions performed by the subjects. Each subject was strapped into the customized testing chair that restrained trunk and lower body movements, but allowed freedom of movement in the head and neck. A static trial was recorded for each subject and for each collar condition. During testing, each subject performed five movement trials to the beat of a metronome set at 50 beats per minute in each of the 12 testing conditions. The metronome was used to standardize the speed of the head-neck rotational movements across subjects to reduce potential bias introduced by differences in angular movement speeds.

Each subject was instructed to reach the end of the full range of motion on the beep of the metronome. For example, during the flexion and extension in the sagittal plane, the subject started in a head neutral position, the metronome began beeping, and then the subject began flexing and extending their head-neck to reach full flexion on the first beep and reach full extension on the very next beep. They were asked to continue this motion without stopping until 5 trials had been recorded. The investigator allowed the subject to go through 2 to 3 full cycles of head motions in each plane before collection began in order to ensure the subject had time to achieve synchronization with the metronome. For consistency, each subject was instructed to stop at the end range of motion in which they felt the collar begin to restrict their motion. The testing order of the collars was first randomized and the movement order was

then randomized for each collar condition to eliminate any ordering or learning effects.

Data Processing and Analysis

3D kinematic data were processed and analyzed using Visual 3D software suite (C-Motion, Inc., Germantown, MD). The rotational direction of the joint kinematics (angles) was determined using a right-hand-rule, and joint angles were calculated using an XYZ cardan rotation sequence. The maximum and minimum of flexion and extension, left and right lateral flexion, and left and right axial rotation, and the total range of motion of each of the three 3D movements for the head-thorax, head-collar, and collar-thorax angles were calculated and determined as variables of interest. Additionally, the head-trunk distraction was calculated for each collar condition. All variables of interest (minus head distraction) were analyzed from a neutral head position, through the full range of motion for each movement, until the head returned to the neutral position. For example, during flexion/extension, the data collection and analysis began when the head was neutral, and went through the full flexion and extension and ended when the head returned to neutral. For the head distraction, the distance between the trunk center of mass and the head center of mass was calculated for each collar condition using the static trial of each of the four collar conditions. Customized computer programs (VB_V2D and VB_Table) were used to determine critical events of the variables of interest from the output of Visual 3D, and were used to organize the variables for statistical analysis.

A 2×4 (Gender x Collar) mixed design analysis of variance (ANOVA) was used to determine any differences between two genders and the three collars for selected kinematic variables (19.0, IBM SPSS, Chicago, IL). Post hoc comparisons were performed using a paired samples t-test if a significant Gender x Collar interaction was found. An alpha level of 0.05 was set a priori for all statistical procedures.

RESULTS

In order to examine the effects of the cervical collars on restrictions of the head-neck 3D movements, we examined the following variables of the angles between the head and trunk

segments: maximum flexion, extension, and total range of motion (ROM: max extension – max flexion) in the sagittal plane, the maximum left and right lateral flexion and total ROM (max right rotation – max left rotation) in the frontal plane, and the right rotation, left rotation and total ROM (max left rotation – max right rotation) in the transverse plane. Ensemble curves of a representative subject for the 3D head-thorax movements are presented in Figure 3 for the no collar condition and in Figure 4 for the XTW collar condition.

The two-way ANOVA results showed no significant gender main effect or gender by collar interaction. Therefore, the data were combined in the subsequent analyses to focus on effects on the collars on the restriction of movements.

For the sagittal plane, the descriptive data and statistical results of the maximum flexion, extension, and total ROM of the head-thorax “joint” are provided in Table 1. The post hoc comparison results showed that the maximum flexion angle, maximum extension angle and total ROM were all reduced significantly for all three collars ($p < 0.001$) compared to the no collar condition (Table 1). The maximum extension angle was reduced in the XTW compared to Vista® TX ($p = 0.011$). In addition, the total ROM was reduced in both Advanced ($p = 0.043$) and XTW ($p = 0.042$) compared to Vista® TX.

The descriptive data and statistical results of the maximum left and right flexion, and total ROM of the head-thorax “joint” in the frontal plane are provided in Table 2. The results indicated that the maximum left and right flexion and total lateral flexion ROM were all reduced significantly in the three collars ($p < 0.001$) compared to no collar (Table 2). The maximum left flexion angle was also decreased in Advanced ($p = 0.002$) and XTW ($p < 0.001$) compared to Vista® TX. Similarly, the maximum right flexion angle and total ROM were also decreased in Advanced ($p < 0.001$ & $p < 0.001$) and XTW ($p < 0.001$ & $p < 0.001$) compared to Vista® TX.

For the transverse plane, the descriptive data and statistical results of the maximum right and left axial rotation and total axial rotation ROM of the head-thorax “joint” are provided in Table 3. The statistical results found that maximum left and right axial rotation angles and total ROM were all reduced significantly in the three collars ($p < 0.001$) compared to no collar (Table 3). In addition, the maximum right rotation and total axial rotation ROM were reduced in

XTW ($p = 0.005$ & $p = 0.005$) compared to Advanced. The peak left axial rotation angle was decreased in XTW ($p = 0.031$) compared to Vista® TX.

For the head and trunk distraction, there was a between-subject gender main effect ($F = 30.8$, $p < 0.001$) and the female subjects had smaller distraction values compared to their male counterparts (Figure 5). The post hoc comparison showed that the distraction was reduced only for XTW compared to no collar ($p = 0.041$, Figure 5).

Table 1. Mean peak flexion, extension, and total flexion-extension ROM of the head in the sagittal plane: mean ± STD.

Variables (deg)	No Collar	Vista® TX	Advanced	XTW	F Value	p
Peak flexion	-56.6±12.1	-14.0±7.1 ^{\$}	-12.6±7.8 ^{\$}	-13.3±6.8 ^{\$}	76.2	< 0.001
Peak extension	50.6±15.8	17.4±7.9 ^{\$}	16.3±7.8 ^{\$}	13.6±5.8 ^{##}	41.2	< 0.001
Total ROM	107.1±21.0	31.4±13.0 ^{\$}	28.9±11.0 ^{##}	27.0±8.7 ^{##}	154.6	< 0.001

Note: ^{\$}: Significantly different than No Collar, [#]: Significantly different than Vista® TX, [@]: Significantly different than Advanced.

Table 2. Mean peak left and right lateral flexion and total lateral flexion ROM of the head in the frontal plane: mean ± STD.

Variables (deg)	No Collar	Vista® TX	Advanced	XTW	F Value	p
Peak left lateral flexion	-35.7±8.1	-20.2±6.3 ^{\$}	-15.9±7.0 ^{##}	-14.7±6.4 ^{##}	56.6	<0.001
Peak right lateral flexion	37.8±7.2	22.6±8.0 ^{\$}	18.3±8.2 ^{##}	16.7±5.9 ^{##}	55.7	< 0.001
Total lateral flexion ROM	73.5±13.5	42.8±13.5 ^{\$}	34.2±14.5 ^{##}	31.4±11.2 ^{##}	90.7	< 0.001

Note: ^{\$}: Significantly different than No Collar, [#]: Significantly different than Vista® TX, [@]: Significantly different than Advanced.

Table 3. Mean peak left and right axial rotation and total axial rotation ROM of the head in the transverse plane: mean ± STD.

Variables (deg)	No Collar	Vista® TX	Advanced	XTW	F Value	p
Peak right axial rotation	-64.9±12.2	-16.3±10.0 ^{\$}	-17.0±10.0 ^{\$}	-12.9±8.1 ^{\$\$@}	218.8	< 0.001
Peak left axial rotation	67.2±12.6	19.1±9.3 ^{\$}	18.6±11.3 ^{\$}	14.4±8.0 ^{##}	228.5	< 0.001
Total axial rotation ROM	132.0±22.9	35.4±18.6 ^{\$}	35.6±20.3 ^{\$}	27.3±15.4 ^{##@}	236.6	< 0.001

Note: ^{\$}: Significantly different than No Collar, [#]: Significantly different than Vista® TX, [@]: Significantly different than Advanced.

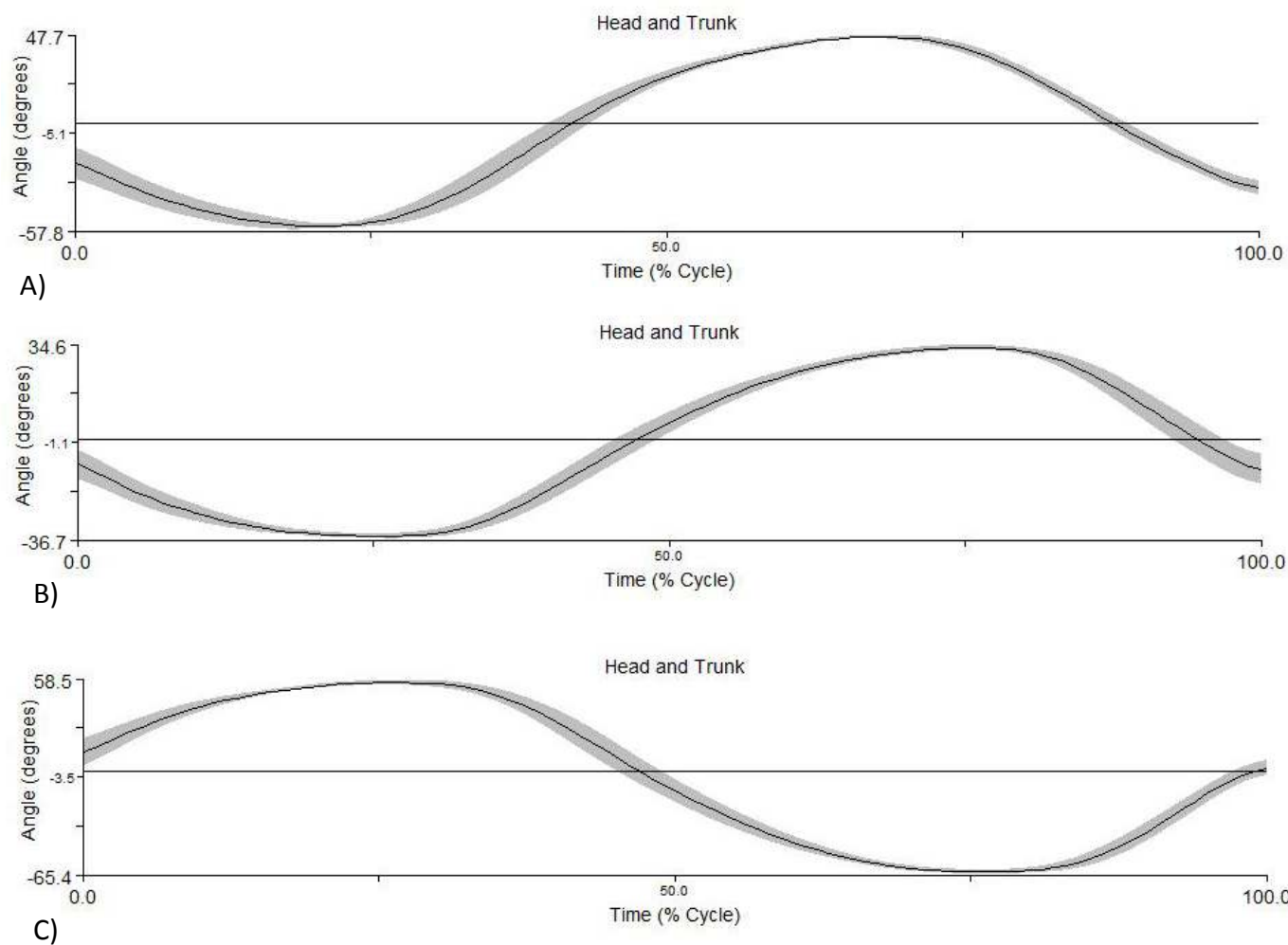


Figure 3. Representative ensemble curves (mean – solid line and shaded area – 1 standard deviation) from one subject in (A) flexion (negative) – extension (positive), (B) left (negative) – right (positive) lateral flexion, and (C) right (negative) – left (positive) axial rotation of head movements in the no collar control condition.

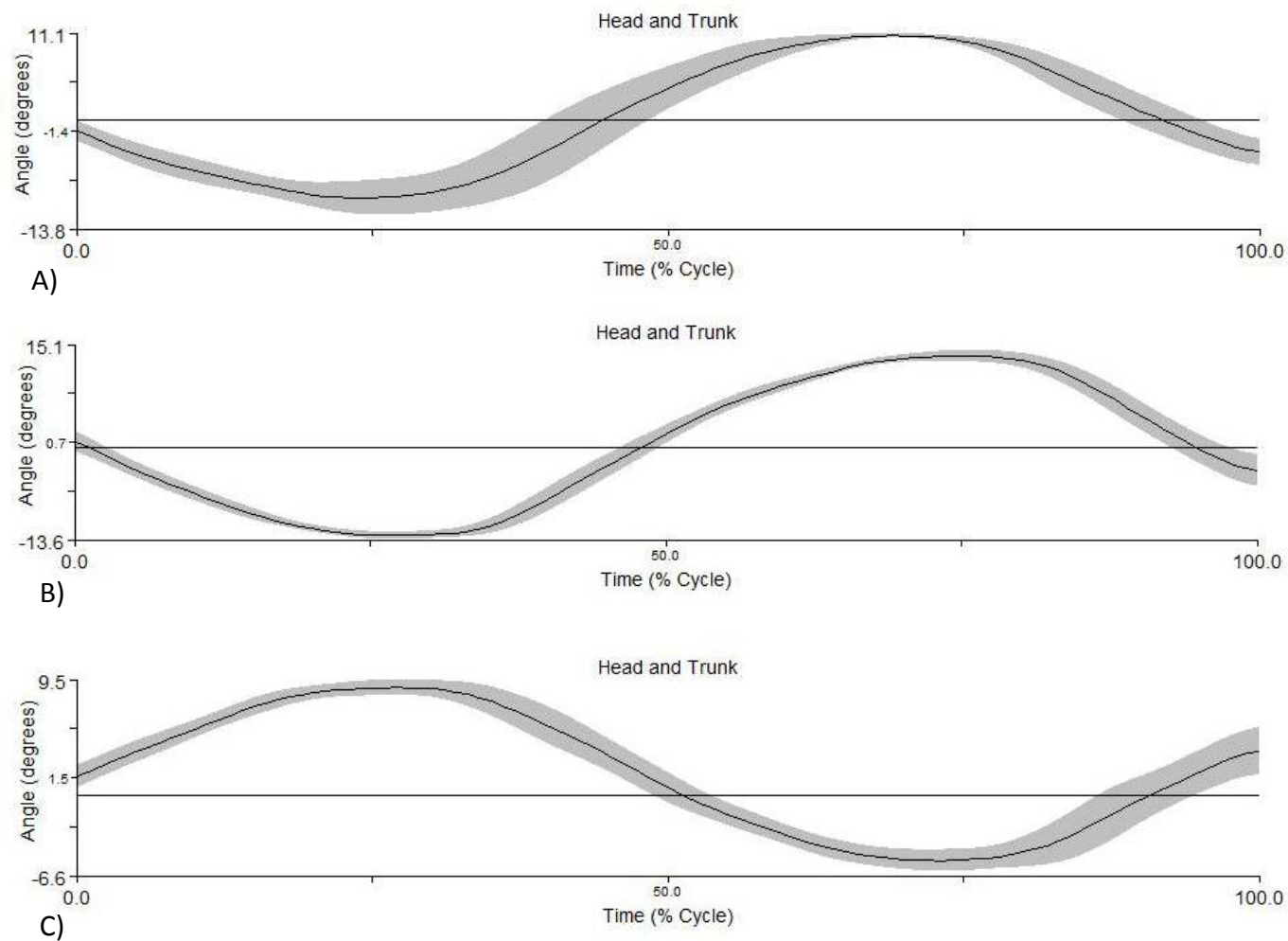


Figure 4. Representative ensemble curves (mean – solid line and shaded area – 1 standard deviation) from one subject in (A) flexion (negative) – extension (positive), (B) left (negative) – right (positive) lateral flexion, and (C) right (negative) – left (positive) axial rotation of head movements in the XTW collar.

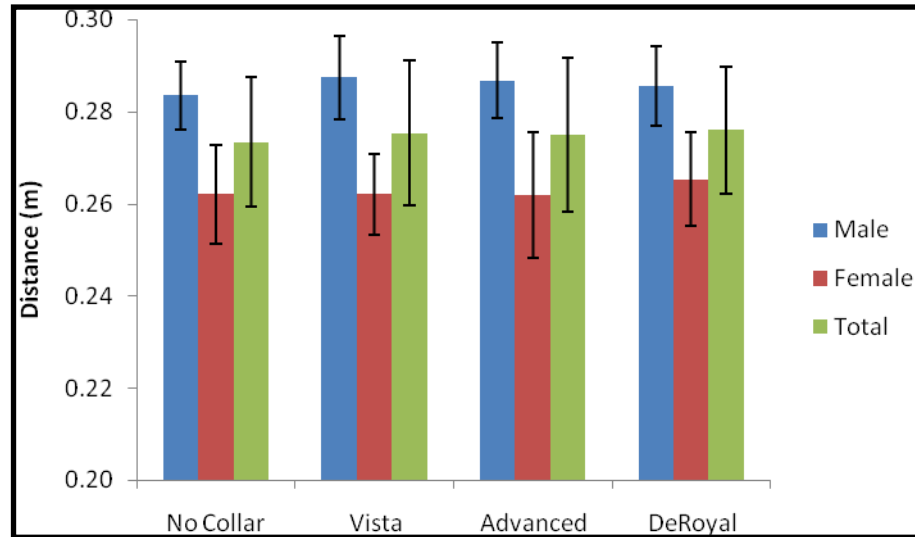


Figure 5. Mean head-thorax distraction values for the four collar conditions for female, male and all subjects.

DISCUSSION

Sagittal Plane Movements

All three collars reduced similar amounts of head flexion ROM (Table 1). The mean reduction of head flexion ROM was 43.3° or 76.5% across all three collars compared to no collar (control condition). Specifically, the reductions were 43.2° (76.4%) for XTW, 42.5° (75.2%) for Vista® TX, and 44.0° (77.8%) for Advanced. The mean reduction of head extension ROM was 34.8° or 68.8%. These reductions were 36.9° (73.0%) for XTW, 33.1° (65.6%) for Vista® TX, and 34.2° (67.7%) for Advanced. There were statistical differences in the amount of reductions among the collars. The XTW collar reduced more head extension ROM than Vista® TX, for an average of 3.7° or 7.4% more reduction. The mean reduction of head sagittal-plane total ROM was 78.0° or 72.8%. Specifically, the reductions were 80.1° (74.8%) for XTW, 75.7° (70.6%) for Vista® TX, and 78.2° (73.0%) for Advanced. The statistical comparisons showed that XTW and Advanced collars reduced more head total ROM compared to the Vista® TX collar, at an average of 4.5° or 4.2% and 2.6° or 2.4% more reduction, respectively.

Frontal Plane Movements

Both XTW and Advanced collars reduced significantly more head left and right flexion ROM and total lateral flexion ROM, compared to the Vista® TX collar (Table 2). The mean reduction of head left lateral flexion ROM for all three collars was 18.8° or 52.6% compared to no collar. The specific reductions of head left lateral flexion ROM were 21.1° (58.9%) for XTW, 15.5° (43.3%) for Vista® TX, and 19.8° (55.5%) for Advanced. Both XTW and Advanced collars reduced more head left lateral flexion than Vista® TX, for 5.6° or 15.5% and 4.3° or 12.1% more reduction, respectively. In addition, the mean reduction of head right lateral flexion ROM was 18.6° or 49.2% for all three collars compared to the no collar condition. The specific reductions of head right lateral flexion ROM were 21.0° (55.7%) for XTW, 15.2° (40.2%) for Vista® TX, and 19.5° (51.6%) for Advanced. Both XTW and Advanced collars reduced more head right lateral flexion than Vista® TX, for 5.8° or 15.5% and 4.3° or 11.4% more reduction, respectively. Finally, the mean reduction of total head lateral flexion ROM was 37.4° or 50.8% for all three collars compared to the no collar condition. The specific reductions of head total lateral flexion ROM were 42.1° (57.2%) for XTW, 30.7° (41.7%) for Vista® TX, and 39.3° (53.5%) for Advanced. Both XTW and Advanced collars reduced more head right lateral flexion than Vista® TX, at 11.4° or 15.5% and 8.6° or 11.7% more reduction, respectively.

Transverse Plane Movements

Both XTW and Advanced collars reduced significantly more head right axial flexion ROM and total axial rotation ROM, compared to the Vista® TX collar (Table 3). The XTW collar also reduced more left head axial rotation compared to Vista® TX. The mean reduction of head right axial rotation ROM for all three collars was 49.5° or 76.3% compared to the no collar condition. The specific reductions of head right axial rotation ROM were 51.9° (80.1%) for XTW, 48.6° (74.9%) for Vista® TX, and 47.9° (73.8%) for Advanced. XTW collar reduced more head right axial rotation than both Vista® TX and Advanced, for 3.3° or 5.2% and 4.0° or 6.2% more reduction, respectively. In addition, the mean reduction of head left axial rotation ROM was 49.8° or 74.2% for all three collars compared to the no collar condition. The specific reductions of head left axial rotation ROM were 52.8° (78.6%) for XTW, 48.1° (71.6%) for Vista® TX, and

48.6° (72.3%) for Advanced. XTW collar reduced more head left axial rotation than Vista® TX, for 4.7° or 7.1% more reduction. Finally, the mean reduction of total head axial ROM was 99.3° or 75.2% for all three collars compared to the no collar condition. The specific reductions of head total axial rotation ROM were 104.7° (79.3%) for XTW, 96.6° (73.2%) for Vista® TX, and 96.5° (73.1%) for Advanced. XTW collar reduced more total head axial rotation ROM than both Vista® TX and Advanced, at 8.1° or 5.1% and 8.3° or 6.2% more reduction, respectively.

Head Distraction

The head distraction values were captured and measured by the distances between the center of gravity of the head and trunk in the static trials for no collar, Vista® TX, Advanced and XTW conditions. As expected, the distraction values were greater for males compared to females. However, there was a significant reduction of this value for the XTW compared to no collar. But the reduction was only less than 1%. Therefore, the adjustable support structure of XTW is not considered to have significant effect of distraction between the head and trunk segment.

Conclusion

In conclusion, the study results demonstrated that both Universal XTW and Miami J Advanced cervical collars had greater effects on restricting head-neck movements in flexion-extension and lateral flexion. However, the Universal XTW collar showed greater restriction on axial rotations of head-neck than Miami J Advanced and Aspen Vista® TX collars. No apparent effects of the adjustable support structure on the head distractions were observed for all three tested cervical collars.

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