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Osmotherly, Peter G.; Farrell, Scott F.; Digby, Shane D.; Rowe, Lindsay J.; Buxton, Anthony J.,  
"The influence of age, sex, and posture on the measurement of atlantodental interval in a  
normal population". Originally published in Journal of Manipulative and Physiological  
Therapeutics Vol. 36, Issue 4, p. 226-231(2013)

Available from: <http://dx.doi.org/10.1016/j.jmpt.2013.04.004>

Accessed from: <http://hdl.handle.net/1959.13/1037332>

**The effect of age, gender and posture on measurement on the atlantodental  
interval in adults.**

Peter G. Osmotherly MMedSci  
Senior Lecturer in Physiotherapy  
School of Health Sciences  
The University of Newcastle,  
Callaghan, NSW 2308, Australia

Scott F. Farrell B.Phty (Hons1)  
School of Health Sciences  
The University of Newcastle,  
Callaghan, NSW 2308, Australia

Shane D. Digby B.Phty (Hons1)  
School of Health Sciences  
The University of Newcastle,  
Callaghan, NSW 2308, Australia

Anthony J. Buxton MHEd  
Senior Lecturer in Diagnostic Radiography  
School of Health Sciences  
The University of Newcastle,  
Callaghan, NSW 2308, Australia

Lindsay J. Rowe. F.R.A.N.Z.C.R.  
Senior Staff Specialist Radiologist  
Hunter New England Imaging, John Hunter Hospital  
Conjoint Associate Professor

School of Medicine and Population Health

The University of Newcastle

Australia

Corresponding author:

Mr Peter Osmotherly.

School of Health Sciences

The University of Newcastle, Callaghan NSW Australia 2308

[Peter.Osmotherly@newcastle.edu.au](mailto:Peter.Osmotherly@newcastle.edu.au)

## ABSTRACT

**Objective:** The atlantodental interval (ADI) is used in assessing atlantoaxial stability. This measurement may potentially be affected by several features encountered during patient examination. This study examined the influence of three features; age, gender and posture, on the measurement of ADI in a normal population.

**Methods:** ADI was measured sequentially on 269 lateral cervical radiographs of adults with no demonstrated bony injury. Images were stratified by age and gender with equal representation in each age-group. A further 25 asymptomatic adults were assessed for posture using craniovertebral angle measured from digital lateral photographs. ADI was then measured from a lateral radiograph. The data were examined for correlation between age, craniovertebral angle and ADI using Spearman's rank correlation. ADI of age-groups was compared by Kruskal-Wallis test. The relationship between ADI and gender was examined using Wilcoxon rank sum test. Interaction between age and gender was explored using an interaction term in regression analysis.

**Results:** ADI decreased with age, median measurements reducing from 2.07mm to 0.85mm across age-groups ( $p < 0.01$ ). No significant relationship was demonstrated between ADI and gender. No significant interaction was demonstrated between age and gender. Measurements of craniovertebral angle did not correlate with ADI ( $p = 0.03$ ,  $p = 0.90$ ).

**Conclusion:** The magnitude of ADI decreases with advancing age. Age should be considered a modifying factor when interpreting measurement of ADI, particularly in

consideration of potential minor instabilities. Gender does not appear to influence ADI, either independently or in interaction with age. Craniocervical posture variation does not influence ADI in an asymptomatic adult population

## INTRODUCTION

The atlantoaxial joint is the most mobile segment of the vertebral column and has the least inherent stability of any of the vertebral articulations<sup>1</sup>. With little osseous stability, maintenance of this region is ensured by the integrity of the craniocervical ligaments, particularly the transverse ligament of the atlas<sup>2, 3</sup> together with an efficient local neuromuscular system<sup>4</sup>. Manual therapists approach the upper cervical region with some caution due to the possibility of atlantoaxial instability<sup>5</sup>. Transverse ligament integrity may be compromised in patients who have experienced trauma<sup>6-10</sup>, infections of the pharynx or neck<sup>11, 12</sup>, rheumatoid arthritis and seronegative spondyloarthropathies<sup>13-16</sup>. Congenital anomalies may also effect stability of the articulation<sup>17-19</sup>.

The atlantodental interval (ADI), defined as the distance between the anterior border of the odontoid process and the posterior inferior border of the anterior arch of the atlas on a lateral radiographic view<sup>20</sup>, is often used to identify instability at the atlantoaxial segment<sup>21</sup>. The normative values for the atlantodental interval for diagnosis of gross atlantoaxial displacement with the potential for spinal cord and lower brainstem compression are well established<sup>11, 22-24</sup>, however, there is less consideration given of relatively minor instabilities which may be potential causes of cervical spine pain and dysfunction treated by manual therapists<sup>3, 25, 26</sup>. The assessment of the atlantodental interval may potentially be affected by a number of factors routinely encountered in patient examination including age and degenerative change, gender and habitual posture and these may also influence published normative values.

The influence of age on this measurement has been previously examined with conflicting findings. Sharp and Purser<sup>27</sup> examined the mid-position cervical lateral radiographs of a convenience sample of 1478 patients. Categorising their results into 0.5mm increments, these authors concluded that an ADI of up to 3mm should be considered normal in people after the age of 44. These findings should be seen in the context that the sample included a number of patients with evidence of rheumatoid arthritis, a disease associated with developing atlantoaxial instability, comprising up to 17% of the individual age strata.

Kharnjanasthiti and colleagues<sup>28</sup> examined ADI's in 400 lateral cervical radiographs seemingly unscreened for pre-existing pathology. These authors demonstrated a trend toward decreasing ADI with increasing age, although this trend was reversed in the 50 to 59 year age group. No consistent association was demonstrated with regard to gender in their sample. The influence of age on ADI is supported by the observations of Hinck and Hopkins<sup>23</sup> who described a gender mediated age effect on measurement, suggesting normative ADI values accounting for age and gender could be calculated using a linear function. In contrast, Frobin and colleagues<sup>29</sup> assessed the ADI in 96 lateral radiographs and concluded that ADI measurements were neither dependent upon age or gender but a function of the depth of the vertebral body of the axis.

The consideration of upper cervical spine posture involves assessment of the excursion of the head relative to the line of gravity<sup>30</sup> and the position of the upper cervical segments in the sagittal plane. The protruded neck position is often of clinical interest since it is frequently associated with a forward head posture<sup>31</sup> and functional sitting positions<sup>32</sup>. Radiographic analysis of sagittal translation in the upper cervical segments has indicated that during protrusion, the atlantoaxial joints approach end of range extension whilst during retraction, the atlantoaxial joints move toward end range flexion<sup>32</sup>. This would infer that the ADI is increased in retracted positions and reduced in protruded positions in individuals without instability of the upper cervical spine.

Examination of upper cervical spine segments in rheumatoid arthritis patients reveals some potentially important variance in considering the effect of sagittal position on ADI in cases where instability may be present. Using lateral radiographs to compare the upper cervical segments of healthy participants and rheumatoid arthritis patients, Karhu and colleagues<sup>33</sup> noted that in a neutral head position, the atlas was oriented in a more flexed position on the axis in the patient group due to a combination of superior migration of the posterior arch of the atlas and developing atlantoaxial subluxation. Measurement of the ADI in positions of protrusion and retraction of the upper cervical spine in a population diagnosed with rheumatoid arthritis reveals a variation in effect of position upon measurement. Whilst retraction was consistently associated with atlantoaxial joint flexion with an anterior translation of the atlas and a consequent increase in ADI, protrusion could result in either atlantoaxial extension with posterior translation leading to a reduced ADI or extension accompanied by an anterior translation of the atlas resulting in a paradoxical atlantoaxial subluxation and



an increase in measured ADI<sup>34</sup>. Hence, both retracted and protruded positions offer the potential risk of atlantoaxial subluxation in individuals in the presence of instability.

The purpose of this study was to examine the influences of age, gender and posture on the measurement of ADI in a normal population to improve understanding of the factors affecting natural variation of this measurement that is frequently used to assess atlantoaxial stability.

## METHODS

Ethical approval for this work was granted by the Hunter New England Human Research Ethics Committee and The University of Newcastle Human Research Ethics Committee.

### Participants

For the assessment of the influences of age and gender, functional radiographic studies for people between the ages of 18 and 91 were obtained from existing patient files held by Hunter New England Area Health Service, Australia. All radiographs were taken as part of routine clinical management of these patients. As is standard clinical practice, all radiographs were taken with the patient in standing. Studies considered eligible for inclusion were reported by a radiologist to be free of pathology. Studies were excluded if there was any indication of fracture or bony injury, head or neck trauma, diagnosed ligamentous injury, congenital cervical

disorders or conditions known to be associated with craniocervical ligament laxity or a patient diagnosis of inflammatory joint disease. Degenerative change commensurate with normal aging was not considered an exclusion criterion. The resulting data set comprised 269 radiographic studies. These were stratified into six age categories with approximately equal gender representation in each.

To assess the influence of posture, twenty-five asymptomatic undergraduate students aged between 19 and 33 years were recruited to participate. Subjects were excluded from the study if they had a history of serious neck trauma, recurrent throat infection or systemic inflammatory disease. Pregnant subjects were also excluded due to the risks associated with exposure to ionising radiation. To minimize the total radiation exposure of subjects, the sample was limited to those who had not undergone any medical imaging involving ionising radiation within the previous five years. The participants in this component of the study comprised 11 females and 14 males with a mean age of 21 years, 8 months. Informed consent was gained from all subjects upon recruitment.

## Procedure

The atlantodental interval was measured from neutral position lateral cervical spine radiographs. Images were viewed and measured using Amicas Viewer 6.0.1.53291 (Amicas, Boston). ADI measurement was performed using a modification of the approach of Yochum and Rowe<sup>24</sup> involving the averaging of three measurements of the perpendicular distance between the posterior aspect of the anterior arch of the atlas and the anterior aspect of the odontoid process obtained at the superior, mid

and inferior levels of the atlantodental cavity (Figure 1). This method accounted for misrepresentation due to irregularity between joint surfaces.

Lateral radiographs of the 25 participants undergoing postural measurement were obtained in erect sitting and taken with a modified technique to reduce participant dose. With a source-image distance of 173cm and the central ray positioned perpendicular to the mid cervical region, an exposure of 80kVp at 6.5mAs was used. This exposure provides a longer scale of contrast than normal cervical spine imaging but reduces patient dose in excess of 50% to a standard clinical series film.

Craniocervical posture was assessed by measurement of the craniovertebral angle from a lateral digital photograph. In accordance with previous descriptions<sup>35, 36</sup>, subjects were seated in a high-backed chair with their feet flat on the floor and hips and knees at 90 degrees. Surface markers were placed on the tragus of the ear and the tip of the spinous process of the seventh cervical vertebra (C7). A free-hanging plumb line was included within the frame of the photograph for the purpose of calculating the true horizontal. Subjects were instructed to place their hands in their laps, look straight ahead and sit as naturally as possible. Craniovertebral angle for each participant were calculated using Adobe Photoshop CS4 (Adobe Systems Incorporated, Los Angeles, CA), as the magnitude of the angle formed between the true horizontal and a line connecting the tragus of the ear and the tip of the spinous process of C7 (Figure 2).<sup>37</sup> The craniovertebral angle provides a measure of the position of the head in relation to the cervical spine<sup>37</sup>. A more acute craniovertebral angle represents a greater degree of forward head posture<sup>37</sup>.

## Statistical analysis

All data analysis was undertaken using STATA 11.0 statistical software (Statacorp, Texas). A Kruskal-Wallis test was used to examine differences in central tendency of ADI between the six age strata. The correlation between measured ADI and age of the combined sample of 269 radiographic studies was assessed using Spearman's rank correlation. Wilcoxon Rank Sum test was used to assess the relationship between ADI and gender within each age group. Interaction between the variables age and gender was explored using multiple regression analysis incorporating the interaction term ageXgender. The correlation between ADI and craniovertebral angle for the 25 participants assessed was determined using Spearman's rank correlation. A p-value of less than 0.05 was considered statistically significant.

## RESULTS

### Relationship of ADI to age and gender

The ADI decreased in magnitude in each age group examined (Figure 3) with the median ADI for the age group 18 to 30 years being 2.07mm, reducing to 0.85mm in the over 71 years age group. The median ADI for each age group is provided in Table 1. Between-group comparisons revealed a statistically significant difference between age groups for median ADI ( $p < 0.01$ ). Spearman's rank correlation between age and ADI was high ( $\rho = -0.74$ ,  $p < 0.01$ ).

The association between ADI and gender is given for each age group in Table 1. No significant relationship was demonstrated between ADI and gender in any age strata examined. The interaction term combining age and gender used in multivariate modeling did not contribute to a model predicting ADI ( $p=0.87$ ). Only age as an independent variable predicted change in ADI in the multivariate model with each additional year of age resulting in a 0.02mm reduction in measured ADI ( $p < 0.01$ ).

#### Relationship of ADI to craniovertebral angle

The median ADI measured in this sample was 1.53 mm (interquartile range 1.40 to 1.60). The craniovertebral angles measured ranged from 37.2° to 59.9° (mean angle = 48.4°, standard deviation 5.6°). Spearman's rank correlation coefficient between craniovertebral angle and ADI in the neutral position was 0.03 ( $p=0.90$ ).

## DISCUSSION

These findings demonstrate the relative influence of three common features of clinical presentation upon the ADI in asymptomatic individuals. Unlike previous studies, the samples examined in this study were subject to explicit a priori inclusion and exclusion criteria and screened by a radiologist for potential disease and risk factors for atlantoaxial instability prior to inclusion. Hence, the ADI values and the associations obtained may be considered representative of the normal adult population.

Measures of ADI obtained in our sample illustrates that this feature does vary with age in adults without evidence of instability, decreasing in size with increasing age.

This decrease in the measured interval with age is reflective of the gradual decrease in volume of the articular cartilage between the odontoid process and the anterior arch of the atlas occurring with aging<sup>38</sup>. The implication of this finding is that interpretation of the ADI needs to consider the age of the individual as a modifying factor. The range of median values derived in this study between 2.10mm in the less than 30 years age group and 0.76mm in the over 70 years age group would suggest that a single normative value for the adult ADI would have limited clinical meaning. Indeed, it would seem quite possible that an ADI in an older individual could be of a magnitude which may be considered hypermobile, or at least worthy of further investigation, without reaching either the distances measured in a younger person with an intact atlantoaxial segment or any adult normative value criterion established on the basis of population averages. Any consideration of the ADI in the existence and contribution of minor instabilities of the upper cervical spine to patient presentation would need to be informed by the age of the individual in addition to the other clinical information derived from patient interview and examination.

No relationship between ADI and gender was demonstrated in any age group in this study suggesting that ADI is not affected by this feature. This result is consistent with previous studies<sup>28, 29</sup> which concluded that gender is not a factor required to be accommodated in the radiological assessment of ADI. It has been observed by past authors that the measured ADI is often less in females than males of the same age group. However, the magnitude of difference rarely reaches statistical significance in direct comparisons. This observation led Hinck and Hopkins<sup>23</sup> to conclude that age effects ADI differently in different genders and that this age-gender interaction could be modelled as a linear regression function. In reproducing their analysis using a

multivariate model containing age, gender and the interaction term ageXgender, the interaction term failed to contribute to the model, the only explanatory variable reaching statistical significance being age which alone explained 51.5% of the variance within ADI in the sample.

The results of this study suggest that there is no influence of cervical spine posture on ADI measurement in asymptomatic individuals. This finding is expected in a group where the osseoligamentous integrity of the occipito-atlanto-axial region is not compromised. This does, however, demonstrate that whilst a patient's age should be considered in interpretation of their ADI, habitual posture will not modify this measurement further in the absence of evidence suggestive of hypermobility. Further exploration of the effect of postural variation in the upper cervical spine on ADI in a group with demonstrable atlantoaxial instability would illustrate any changes in ADI which would result from initial flexion of the atlas on the axis due to pre-existing hypermobility<sup>1, 33</sup>. It would also be informative in understanding whether the paradoxical translation of the atlas during cervical spine protrusion described by Maeda et al<sup>34</sup> is evident in individuals exhibiting protruded cervical spine postures. The sample analysed in the postural analysis component of this study were intentionally recruited within a limited age range. This provided greater homogeneity to mitigate the effects of age on the measurements of ADI obtained.

## LIMITATIONS

There is notable variation in the published descriptions of ADI measurement, all of which are variations on the description of the distance between the anterior border of

the odontoid process and the posterior inferior border of the anterior arch of the atlas. In this study, the technique suggested by Yochum and Rowe<sup>24</sup> was adopted whereby the participants were placed in a neutral neck position. This imaging position differs from some other studies where lateral images were obtained in neutral, flexed and extended positions<sup>21, 39</sup>.

Measurements of craniovertebral angle obtained from our participants contained few estimates that would be considered to be at the high or lower end of the spectrum of craniovertebral angle measurement. This may have exerted some influence on the results obtained as ADI was examined within a limited range habitual craniocervical postures. By excluding individuals with current neck pain from this component of the study, it is also possible that people with more extreme craniovertebral angle measurements were effectively excluded from the study given the established association between more extreme craniovertebral angles and neck pain<sup>30</sup>.

## CONCLUSION

The magnitude of ADI decreases with increasing age and the age of a patient should be considered in interpreting the ADI, particularly when the potential for minor clinical instability is present. Gender does not appear to be associated with ADI either as an independent factor or in an interactive context together with patient age. Normal craniocervical posture variation does not influence ADI measurement in people with no neck symptoms and no hypermobility evident. However, given the findings of research in rheumatoid arthritis populations, the potential for sagittal plane head and



neck position to influence ADI in populations where potential instability or hypermobility is present requires examination.

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## TABLE AND FIGURE LEGENDS

Table 1. Median ADI measurements and between gender comparisons for each age-group.

Figure 1. Measurement of the atlantodental interval (ADI). The ADI was calculated as the average of the superior (AB), mid (CD) and inferior (EF) measurements.

Figure 2. Craniovertebral angle measured as the angle formed between a line running from the tragus of the ear to the spinous process of C7 (interval AB) and the true horizontal (interval BC).

Figure 3. ADI measurement stratified by age group

Table 1

Age group	Median ADI in mm (IQR)	Between gender comparison (p-value)
18-30 years		
Male (n=22)	2.10 (1.83 to 2.33)	0.62
Female (n=22)	1.94 (1.44 to 2.41)	
Combined (n=44)	2.07 (1.69 to 2.41)	
31-40 years		
Male (n=22)	1.65 (1.42 to 2.06)	0.46
Female (n=22)	1.59 (1.34 to 1.74)	
Combined (n=44)	1.61 (1.42 to 1.78)	
41-50 years		
Male (n=22)	1.27 (1.09 to 1.42)	0.86
Female (n=23)	1.27 (0.94 to 1.44)	
Combined (n=45)	1.27 (1.02 to 1.44)	
51-60 years		
Male (n=22)	1.05 (0.94 to 1.36)	0.95
Female (n=23)	1.12 (0.91 to 1.30)	
Combined (n=45)	1.07 (0.94 to 1.33)	
61-70 years		
Male (n=23)	0.93 (0.82 to 1.15)	0.57
Female (n=23)	0.93 (0.73 to 1.08)	
Combined (n=46)	0.93 (0.77 to 1.08)	
71+ years		
Male (n=22)	0.93 (0.77 to 1.11)	0.15
Female (n=23)	0.76 (0.70 to 0.96)	
Combined (n=45)	0.85 (0.72 to 1.05)	

Figure 1



Figure 2

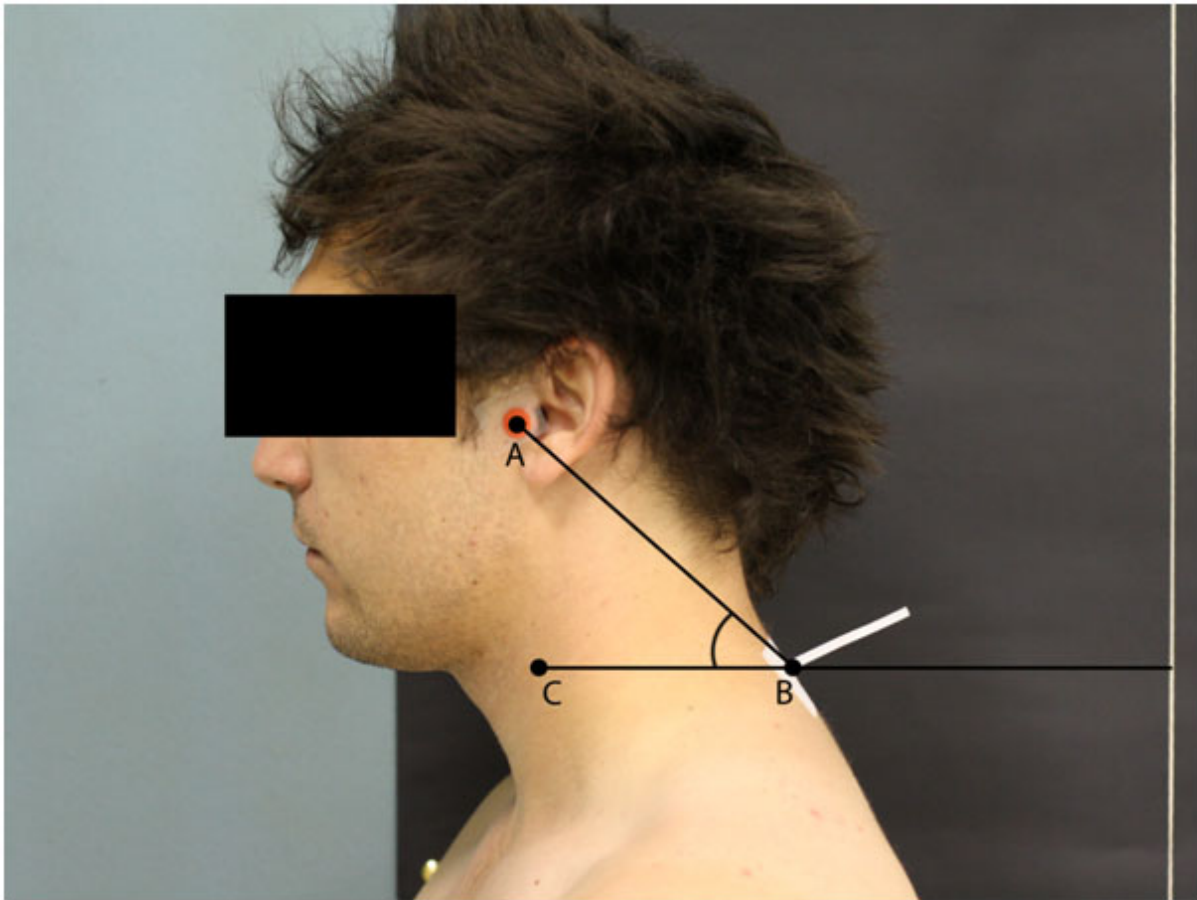




Figure 3

