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DIMENSIONS OF THE CERVICAL SPINAL CANAL IN THE SOUTH AFRICAN NEGROID POPULATION

By

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ABSTRACT

Dimensions of the cervical spinal canal in the South African negroid population

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The dimensions of the cervical spinal canal (C3 – C7) of the South African black population were measured on skeletal remains of 179 individuals (90 males and 89 females divided into age categories of 30-45; 46-60 and 61-75 years), and compared to measurements taken from CT-scans of 55 individuals divided into the same categories. There was no significant difference between measurements taken on skeletal material and CT-scans.

The spinal canal is larger in males (mean = 13.96mm) than in females (mean = 13.84mm) and the Pavlov ratio is larger for females (mean = 0.89) than males (mean = 0.81). The Pavlov ratio seems to overestimate the occurrence of spinal stenosis in this population group, as almost all individuals older than 46 years are classified as stenotic according to this ratio.

The shape of the cervical spinal canal was determined morphometrically by processing digital images taken of vertebrae (C3 – C7) of 60 individuals with the tps-Series of software programs and was found to be significantly different between males and females. In males the canal is congenitally triangular, whereas in females the canal assumes a more “safe”, rounded shape. The low Pavlov ratio for this population group, especially in males, can possibly be explained by these shape differences. Even slight degenerative changes affecting the spinal canal, such as osteophytosis or ossification of the posterior longitudinal ligament (OPLL), will alter the triangular-shaped male canal in such a way that the spinal cord may become compromised.

Cervical vertebrae of 107 individuals were inspected for occurrence of osteophytes within the spinal canal and the incidence of OPLL. Osteophyte occurrence within the cervical spinal canal is the same for males and females and OPLL occurs frequently within this population group, especially in the cephalic region (incidence: C3 = 64.5%; C4 = 47.7%; C5 = 21%; C6 = 12.2%; C7 = 7.5%).

OPSOMMING

Gizelle Tossel

Dimensies van die servikale spinale kanaal in die Suid-Afrikaanse swart bevolking

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Die dimensies van die servikale spinale kanaal (C3-C7) in die swart Suid-Afrikaanse bevolking was gemeet op skeletale materiaal van 179 individue (90 mans en 79 vroue, opgedeel in ouderdomsgroepe van 30-45; 46-60 en 61-75 jaar oud) en vergelyk met metings geneem op CT-skanderings van 55 individue opgedeel in dieselfde ouderdomsgroepe.

Die spinale kanaal is groter in mans (gemiddeld = 13.96mm) as in vroue (gemiddeld 13.84mm) en die Pavlov ratio is hoër in vroue (gemiddeld = 0.89) as mans (gemiddeld = 0.81). Dit wil voorkom asof die Pavlov ratio die voorkoms van servikale spinale stenose oorskat, siende dat amper alle individue ouer as 46 jaar geklassifiseer word as stenoties volgens die ratio.

Die vorm van die servikale spinale kanaal was morfometries bepaal deur digitale foto's van die werwels (C3 - C7) van 60 individue met die tps-Reeks sagteware te analiseer. Dit het 'n betekenisvolle verskil tussen die geslagte aangetoon. In mans is die kanaal van nature driehoekig, terwyl dit in vroue `n "veiliger" ronder vorm het. Die lae Pavlov ratio vir hierdie studiebevolking, veral in mans, kan moontlik verduidelik word deur hierdie vorm verskille. Selfs effense degeneratiewe veranderings soos osteofitose of ossifikasie van die posterior longitudinale ligament (OPLL), sal die driehoekige kanaal van mans sodanig verander dat dit druk op die spinale koord kan uitoefen.

Servikale werwels van 107 individue was ondersoek vir die voorkoms van osteofiete en OPLL. Die voorkoms van osteofiete binne-in die servikale spinaal kanaal is dieselfde vir beide geslagte en OPLL kom dikwels voor in hierdie bevolkingsgroep, veral in die kefaliese streek (voorkoms: C3 = 64.5%; C4 = 47.7%; C5 = 21%; C6 = 12.2%; C7 = 7.5%).

TABLE OF CONTENTS

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

LIST OF FIGURES

LIST OF TABLES

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

LIST OF GRAPHS

1. INTRODUCTION

Although spinal stenosis has been recognised for many years as a clinical diagnosis, it has yet to be exactly defined and agreed upon. This lack of definition leads to difficulties in comparing and interpreting studies of the prevalence, incidence and treatment thereof[1]. This could in part be due to differences in spinal canal dimensions that exist between population groups as documented by various authors[2,3,4,5].

Cervical spinal stenosis is understood to be a narrowing of the cervical spinal canal and is associated with compression of the spinal cord[6]. A midsagittal spinal canal diameter of less than 12mm is believed to be indicative of cervical spinal stenosis[6], and is observed frequently in patients experiencing neurological symptoms related to those of cervical spinal stenosis. Torg[7] goes as far as stating that the determination of cervical spinal stenosis requires the demonstration of a sagittal diameter of the spinal canal of less than 14mm from C4 to C6.

Although spinal stenosis is mainly a disease associated with the elderly[8,9], cases of developmental cervical spinal stenosis[10], occurrence of stenosis in children[11] and cervical stenosis associated with Down's syndrome[12] are also documented. Correct diagnosis of cervical spinal stenosis is greatly responsible for quick and accurate treatment of the associated pathology and to ensure optimal treatment and procedural outcome[13].

Undiagnosed cervical spinal stenosis may have severe complications as was cited by Fujioka *et al.,* where an extended neck position during coronary artery bypass grafting caused tetraplegia, presumably because the position may have aggravated an occult pre-existing cervical spinal canal stenosis which then produced cervical injury[14].

Compression of the spinal cord might be expected when the sagittal diameter of the spinal canal is below the lower limit of normal (approximately 12mm)[6]. However, as shown in the study of Postacchini *et al.*,, the 12mm guideline dividing stenotic spinal canals from non-stenotic spinal canals (that is currently universally applied) may have to be reconsidered, as high proportions of their study sample had mean sagittal diameters of less than 12mm, observed among two ethnic study groups[15].

Significant variation in the dimensions of the cervical spinal canal precludes the usage of universal definitions to determine the presence of spinal stenosis in individuals. These definitions should rather be based on sex and descent[16]. Before abnormal spinal morphometry can be determined, normal values need to be established for the specific population being evaluated[17].

The question arises as to whether standards applied to other population groups can be applied to the South African Negroid population to define what is normal and abnormal in terms of dimensions of the cervical spinal canal, especially when considering that statistically significant differences have been found to exist between population groups in various other studies[2,3,4,5].

According to Statistics South Africa's mid-year population estimates for 2006[18], 79.5% of the South African population is African (Black) – that amounts to 37 million individuals, and as such justifies an in-depth study to establish clear anatomical guidelines that includes the dimensions of the cervical spinal canal to aid in correct diagnosis of pathology in the area, as well as to determine whether there is a correlation between the dimensions of this study population and that of other population groups.

Very few studies have been done to determine the changes in the cervical spinal canal that occur with increasing age. This could entail change of the shape of the spinal canal, narrowing of the spinal canal (cervical spinal stenosis) and the formation and distribution of osteophytes which could cause compression of the spinal cord and impingement of spinal nerves.

Pathology and stenosis of the cervical area is mostly in the sagittal plane. However, a narrow sagittal spinal canal diameter by itself might not indicate a significant decrease in the area of the canal[19].

In a method designed by Pavlov *et al.,*, the sagittal diameter of the cervical spinal canal in relation to the sagittal diameter of the corresponding vertebral body is said to be a reliable indicator of cervical spinal stenosis[20]. In normal individuals, the ratio is close to 1 and where the ratio is less than 0.82 stenosis is said to be present. A ratio of below 0.8 is believed to be a significant risk factor for lateral neurological injury and establishes a canal to be congenitally narrow. Results obtained when using the ratio is said to be independent of technical factor variables[20]. Suspicion of cervical spinal myelopathy is supported by the finding of a spinal canal sagittal diameter less than 11cm and Pavlov's index less than 0.8[21].

However, studies done on different population groups yielded contradicting results in terms of the validity of the application of the Pavlov ratio. A study on adult Koreans indicated that the canal/body ratio is a more reliable method for determining cervical spinal stenosis or predicting cervical spinal cord injury, than directly measuring the sagittal diameter of the spinal canal in this area[3], while a study done on a Japanese study population comparing the vertebral body/canal ratio between males and females concluded that the anteroposterior measurement of the vertebral body correlated highly with the size of the spinal canal in males, but not in females[22].

Prasad *et al.,* (2003) found that there was a poor correlation between Pavlov's ratio and the space available for the spinal cord, and concluded that this ratio cannot be used as the only method to predict changes in the sagittal plane of the cervical spinal canal[19].

This ratio is currently used as a universal indicator of cervical spinal canal stenosis in spite of the fact that differences between race and sex have been reported[4].

There exists a direct correlation between the dimensions of the cervical spinal canal and its association with neurological consequences after trauma[23]. The dimensions of the canal can influence the probability that an individual will suffer prolonged effects after a spinal injury in that area and it can also influence the recovery time[16].

It also has to be considered that various other factors pertaining to the dimensions of the cervical spinal canal may influence spinal pathology and cause neurological symptoms. These include the shape of the spinal canal[24,25,10], the age of the patient[26,27,28], the sex of the patient[27], pathology in the associated regions directly affecting the canal such as osteophytosis[29] and ossification of the posterior longitudinal ligament[30,31,32].

The shape of the spinal canal has mostly been studied in the lumbar region[24,33,34] and, as such, leaves opportunity for study and definition in the cervical region, specifically in the South African Negroid population where no study has yet been done to determine the shape of the cervical spinal canal.

Many authors agree that the shape of the spinal canal may greatly influence the occurrence of pathological conditions, such as spinal stenosis and predisposition to spinal cord injury with enough trauma[24,25,10], with the trefoil shape being the most problematic[10]. Some authors believe that the trefoil shape is a common non-pathological condition when encountered in the lumbar area[33,34].

The shape of the spinal canal is generally classified into 4 categories: the trefoil shape (narrow spinal canal, long nerve root tunnel and shallow lateral recess) lends itself to cause radicular disturbances; the triangular shape (wide spinal canal, long nerve root tunnels and small lateral recess) manifesting neurological symptoms such as radicular disturbances and intermittent claudication; the round canal (wide spinal canal, short nerve root tunnel and wide lateral recess) is considered to be "safe" and causes no neurological deficits; and the intermediate shape showing clinical characteristics varying between the previously mentioned three groups[24].

Matsuura *et al.,* describe the shape of the cervical spinal canal as a ratio of the sagittal canal diameter to the transverse canal diameter. They conclude that by measuring the shape as a ratio, no evaluation of an individual on the basis of absolute measurements is necessary. Their findings also suggest that a predisposition to spinal cord injury due to trauma depends more on the shape of the spinal canal than on the volume of space in the canal[25].

Various studies confirm that the sagittal diameter of the cervical spinal canal decreases with age[27,28,35]. Growth of the spinal canal starts declining at age seven to eight years[36].

A comparative study was done on the South African Negroid population by Taitz[2] to determine, amongst other things, if the dimensions of the cervical spinal canal changes with age. Although Taitz concluded that there was no apparent change in the dimensions occurring with age, it has to be considered that the sample size was small (as recognised by the author in a subsequent publication relating to the same material[29]), which leaves room for elaboration and discovery in this area of study.

The cervical spinal canal is found to be consistently narrower in females than in males[27,4]. Hukuda and Kojima compared the body/canal ratio between males and females and concluded that the anteroposterior measurement of the vertebral body correlated well with the size of the spinal canal in males, but not in females. The ratio was found to be significantly higher in females than in males. A significantly high body/canal ratio in males may implicate the prevalence of cervical myelopathy[22].

The study by Taitz[2] on the South African Negroid population found no significant differences between males and females, but here too the small sample size is a limiting factor for accuracy of the results.

Degenerative changes of the cervical vertebral bodies and cervical intervertebral discs (cervical spondylitic myelopathy) cause disturbances to the spinal cord either by disturbing the blood supply or directly compressing the cord[26].

Vertebrolisthesis (movement of the vertebral bodies in relation to each other), and especially retrolisthesis in an anteroposterior direction, may lead to the movement of a vertebral body into the spinal canal with subsequent stenosis of the canal[28]. Development of posterior osteophytes on vertebral bodies may have the same effect[28], depending on the severity of the osteophytosis. Cervical spinal disorders like spondylitic radiculopathy are often related to osteophyte formation[37].

Occurrence of osteophytes and age of onset is of anthropological importance as development of osteophytes on the vertebral skeleton is used as a general indicator of age at time of death[38].

The study by Taitz[29] on the South African Negroid population indicated clearly that there was a marked difference between the occurrence and distribution of osteophytes in the cervical region between South African blacks and whites. Osteophytes occurred significantly less in the black population than in the white, and in the black population there was a greater tendency for osteophyte occurrence either on the vertebral bodies or on the apophysial joints, but not on both areas. The study showed no significant differences between males and females and, although a difference is described between a "younger" group (30-59 years) and an "older" group (60+ years), the age of osteophyte onset was not clearly established.

Ossification of the posterior longitudinal ligament (OPLL) also causes encroachment of the spinal canal and contributes to a narrower sagittal spinal canal diameter[30] with subsequent compression of the spinal cord[39]. Neurological deficits associated with OPLL are associated with the size of the spinal canal[40]. Patients with OPLL may present with acute spinal cord injury after minor trauma[41]. In a study by Koyanagi *et al.,* the midsagittal diameter of the spinal canal was reduced to values of between 2.9mm and 10mm due to OPLL[40].

Motor deficits in the lower extremities were more frequently observed in patients where the sagittal diameter of the spinal canal narrowed to less than 8mm[40]. Also, the developmental size of the canal was significantly smaller in the patient group with segmental OPLL[41].

No studies have been done in the South African Negroid population to determine the occurrence of OPLL in the cervical spine, the age of onset of OPLL, levels most affected by OPLL, or differences between males and females in terms of these areas, in spite of the fact that it is a well recognised cause of spinal stenosis and myelopathy in the elderly[42] and in various population groups[41,42].

Although the spinal canal has been studied with various imaging techniques such as MRI[43], ultrasound[44] and computed tomography (CT-scans)[25,45], most studies involving the determination of the cervical canal dimensions have been radiographic[16] and plain radiographs overestimate the diameter of the spinal canal[46].

Various congenital and developmental abnormalities of the vertebra, like spinal stenosis, are optimally assessed using computed tomography[45]. Computerised tomography (CT) has been described as a sophisticated and non-invasive procedure to study the nerve root tunnel and vertebral column[47]. A large number of studies have been done on the spinal canal using computerised tomography. Thin section CT imaging seems to be described the most and its uses in studies measuring sagittal and transverse diameters as well as the cross-sectional area of the spinal canal are well documented[48,25,49]. Sections at the level of the pedicles are often used to clearly view of the spinal canal, vertebral bodies and dural sac[50].

Few studies have been done on skeletal material to determine inter-population differences of the spinal canal in the absence of soft tissue[16] and a study has yet to be done to compare findings of the cervical spinal canal dimensions on physical skeletal material and the dimensions as measured on CT-scans within a specific population group.

It is important to evaluate and compare these dimensions with those of other population groups in order to establish the reliability of applying universal standards in a clinical setting for determination of pathology in the associated area, and for differentiation purposes in the anthropological context.

This study is therefore aimed at a comprehensive determination of the dimensions of the cervical spinal canal in the South African Negroid population, both on skeletal material and CT-scans in order to establish clear anatomical guidelines for both the anatomist and anthropologist.

2. AIMS AND OBJECTIVES OF THE STUDY

Focusing particularly on the South African Black population, the aims of this study are to:

2.1 Determine on skeletal material:

2.1.1 The mid-sagittal diameter of the cervical spinal canal

2.1.2 The mid-sagittal diameter of the corresponding vertebral body

2.1.3 The Pavlov ratio for each vertebral level (mid-sagittal diameter of the cervical spinal canal / the mid-sagittal diameter of the corresponding vertebral body)

2.1.4 Morphometric dimensions of the cervical spinal canal in order to determine the shape of the canal

2.1.5 Occurrence of osteophytes (position and severity of osteophytes) within the cervical spinal canal

2.1.6 Occurrence of ossification of the posterior longitudinal ligament (OPLL) within the cervical spinal canal

2.2 Determine on CT-scans

2.2.1 The mid-sagittal diameter of the cervical spinal canal

2.2.2 The mid-sagittal diameter of the corresponding vertebral body

2.2.3 The Pavlov ratio for each vertebral level (mid-sagittal diameter of the cervical spinal canal / the mid-sagittal diameter of the corresponding vertebral body) (C3 to C7)

2.3 Determine statistically if differences exist between

2.3.1 Males and females in terms of:

2.3.1.1 The mid-sagittal diameter of the cervical spinal canal

2.3.1.2 The Pavlov ratio for each vertebral level (C3 to C7)

2.3.1.3 The shape of the cervical spinal canal

2.3.1.4 The occurrence of osteophytes (position and severity of osteophytes) within the cervical spinal canal

2.3.1.5 The occurrence of ossification of the posterior longitudinal ligament (OPLL) within the cervical spinal canal

2.3.2 Age groups in terms of:

2.3.2.1 The mid-sagittal diameter of the cervical spinal canal

2.3.2.2 The Pavlov ratio for each vertebral level (C3 to C7)

2.3.2.3 The shape of the cervical spinal canal

2.3.2.4 The occurrence of osteophytes (position and severity of osteophytes) within the cervical spinal canal

2.3.1.5 The occurrence of ossification of the posterior longitudinal ligament (OPLL) within the cervical spinal canal

2.4 Determine

2.4.1 The narrowest level of the cervical spinal canal

2.4.2 If the cervical spinal canal changes in size from C3 to C7

2.4.3 If the dimensions measured on the skeletal material and the dimensions measured on the CT-scans can be correlated

2.5 Establish if a correlation exists between the South African black population and other population groups (by comparing results from previous studies done on other population groups by other researchers) in terms of:

2.5.1 The mid-sagittal diameter of the cervical spinal canal

2.5.2 The applicability of the Pavlov ratio

2.5.3 The narrowest level of the cervical spinal canal

2.5.4 Dimensional differences of the cervical spinal canal between males and females

2.5.5 Dimensional differences of the cervical spinal canal between age groups

2.5.6 The occurrence of osteophytes (position and severity of osteophytes)

3. LITERATURE REVIEW

3.1 Anatomy of the cervical spinal canal

3.1.1 General vertebral structure

A typical vertebra consists of a vertebral body (the anterior, more massive part of the bone giving strength to the vertebral column and supports body weight), a vertebral arch (posterior to vertebral body, formed by the right and left pedicles and laminae) and articulation processes. Typical vertebrae differ from each other per region; however, their basic structure remains the same[51].

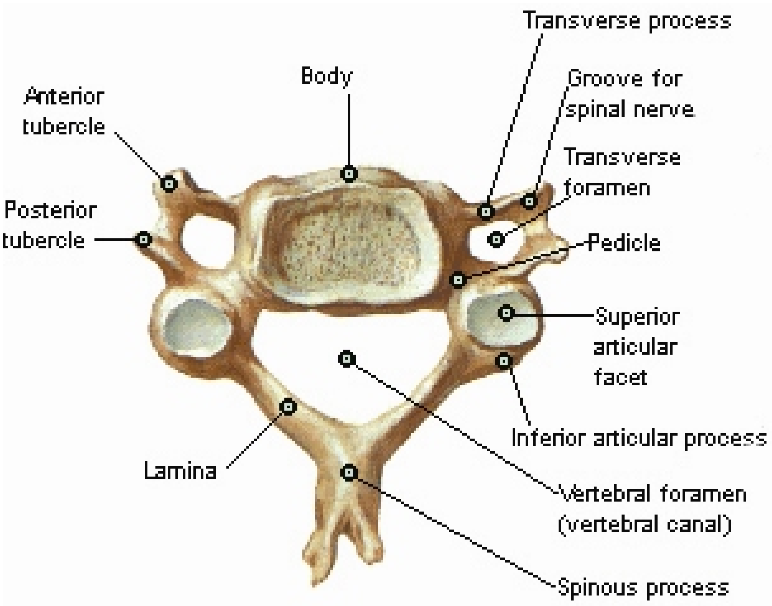


Figure 1. *Typical cervical vertebra (Illustration from: Atlas of Human Anatomy[52])*

The vertebral arch and the posterior aspect of the vertebral body form the vertebral foramen. The successive vertebral foramina form the spinal canal which contains the spinal cord, meninges, fat, spinal nerve roots and blood vessels[51].

3.1.2 Cervical vertebrae

The distinctive features of the cervical vertebrae are the presence of the transverse foramina through which the vertebral arteries pass (except C7, where the foramina may be small or absent, and if present allows passing of the accessory vertebral veins). C3 to C7 are characterised by large triangularly shaped vertebral foramina that are due to the cervical enlargement of the spinal cord providing the innervation of the upper limbs with a triangular shape. The spinous processes of C3 to C6 are short and usually bifid in white persons but not in black persons[51].

Figure 2. *Cervical vertebra with bifid spinous process characteristic of white persons*[51]

Figure 3. *Cervical vertebra with n non-bifid spinous process characteristic of black persons*[51]

The atlas (C1) and the axis (C2) are atypical cervical vertebrae and have different dimensions and structures[51].

3.2 Development of the vertebral column

During the fourth week of embryological development, the vertebral column starts its development with the shifting of the sclerotome positions to surround both the notochord and the spinal cord. The sclerotomic blocks are separated by intersegmental arteries, which are found in the less dense areas that separate the blocks. During the further development of the sclerotomes the caudal portion proliferates and condenses to such an extent that it projects into the subjacent intersegmental tissue and the caudal portion of the sclerotome becomes bound to the cephalic half of the subjacent sclerotome. Subsequently the intersegmental tissue becomes incorporated into the pre-cartilaginous vertebral body. The vertebral shapes and patterns are determined by the *HOX* genes[53].

The intervertebral disc is formed by the remaining less dense mesenchymal tissue that remains between the cephalic and caudal part of the original sclerotome. The notochord regresses in its entirety in the region of the vertebral body, but remains in the region of the intervertebral disc and enlarges. Here it contributes to the nucleus pulposus of the disc which later becomes encircled by the circular fibres of the annulus fibrosus[53].

The rearrangement of the sclerotomes causes the myotomes to bridge the gap between the newly formed vertebrae and over the intervertebral disc, and these alterations provide them with the capacity to move the spine. Also, this new arrangement causes the intersegmental arteries to lie between the vertebral bodies, while the spinal nerves move to lie near the intervertebral discs and they leave the vertebral column through the intervertebral foramina[53].

3.2.1 Prenatal Development

Ursu, Porter and Navaratnam observed that after 30 weeks of gestation, the cranial lumbar vertebrae grow more rapidly than their caudal counterparts which would protect them should a growth impairment occur in early infancy[54]. Typical vertebrae begin ossification from the eighth week of gestation and continue throughout the foetal period[51].

3.2.2 Postnatal development

Three primary ossification centres develop per cartilaginous vertebra. These are located in the centrum and in each of the half of the vertebral arch. At time of birth the caudal sacral vertebrae and the coccygeal vertebrae are still cartilaginous and they begin ossification during infancy. At birth the two halves of the neural arch articulate with the centrum at cartilaginous neurocentral joints. The two halves of the vertebral arch begin fusion during the first year and fusion in the lumbar region is completed after approximately six years of age. The fusion of the vertebral arch to the centrum occurs during childhood between the age of five and eight years[51].

Five secondary ossification centres start their development during puberty in each typical vertebra - one at the tip of the spinous process and of each transverse process, and two annular epiphyses – superior and inferior to the centrum. These annular epiphyses normally unite with the vertebral body early in adulthood. All secondary ossification centres are usually united with the vertebra at the age of 25 but the times of their union may vary. Exceptions to typical ossification patterns include those of C1, C2 and C7 as well as the lumbar, sacral and coccyx[51].

In a study by Ogden on cadaveric material of skeletons ranging from full term neonates to 14 years it was observed that in all specimens ossification was present in both posterior neural arches at birth and that these ossification centres proceeded into the rudimentary spinous process forming the posterior synchondrosis as well as anteriorly into the region of the articulation facet. All the bone that is present in the articulation facets originates from these posterior ossification centres. On the anteromedial aspect of each facet a neurocentral synchondrosis is established on either side of the anterior ossification centre which is expanding. The anterior ossification centre presents itself between the ages of six months and two years. A single anterior ossification centre is the norm, but multifocal anterior ossification was observed in some instances.

Occasionally but infrequently the posterior ossification centres extended into the anterior arch and formed an anterior synchondrosis. Both the anterior neurocentral synchondroses as well as the posterior synchondroses were observed to be fused by age of four to six years. It is believed that all three the centra fuse at the same time, although the posterior synchondrosis often precedes its anterior counterparts. Consequently it is at this age that C1 reaches its maximum size. Further growth occurred only on the external surface by periosteal addition which leads to thickening and increased height, but these do not significantly alter the size of the spinal canal[55].

Wang *et al.,* studied children from age three months to skeletal maturity. Their results show that in both males and females a Torg ratio (ratio of vertebral body sagittal diameter to spinal canal sagittal diameter[20]) of 1.47 was prevalent whilst at maturity the ratio declined to 1.06 for males and 1.10 for females. They also found that the anterior arch of the first cervical vertebra had ossified in 33% of the patients by age three months and it had done so in 81% of the patients by age of one year. Closure of the synchondroses was apparent in all children by age three years[56].

Robinson, Northrup and Sabo also established that the ratio of the sagittal diameters of the vertebral body to the spinal canal decreases steadily from the paediatric age group at various ages through to the adult groups. Adjacent age groups demonstrated a statistically significant decrease with all groups except the oldest two. They conclude that as the paediatric spinal canal renders itself vulnerable to intracanalicular influences, this consistent decrease in the ratio can be used in the early identification of disease processes[57].

Remes *et al.,* observed that growth of the spinal canal declines after age seven to eight years. The sagittal spinal canal diameter to vertebral body depth ratio remains below one at all levels and starts to decline slowly at the age of seven to eight years. They also noted that vertebral bodies grow more in height than in depth and more actively during puberty[58]. Important differenced between the child and adult spine disappear at an age of approximately ten years[59].

Achondroplasia in patients is often associated with spinal stenosis. Cervical spinal stenosis involving the craniospinal junction is more commonly found in children whilst the thoracolumbar stenosis more often favours adults[60].

3.2.3 Curvatures of the vertebral column

The adult vertebral column has four curvatures: cervical, thoracic, lumbar and sacral. The thoracic and sacral curvatures are concave anteriorly whereas the cervical and lumbar curvatures are concave in the posterior direction. The thoracic and sacral curvatures are the primary curvatures which develop during the foetal period and these curvatures are caused by the differences in height between the anterior and posterior aspects of the vertebrae.

The cervical and lumbar curvatures are secondary curvatures that commence their appearance in the foetal period but are only clearly evident during infancy. The secondary curvatures are caused by the difference in thickness between the anterior and posterior aspects of the intervertebral discs[51].

As an infant starts to hold its head erect, the cervical curvature becomes evident whereas the lumbar curvature becomes pronounced when the infant starts to walk and assumes an upright posture[51].

3.2.4 Vertebral column defects

3.2.4.1 Upper vertebral column congenital abnormalities

Congenital malformations in the upper cervical region, especially that of C1 is very rare. In a case study done by Phan *et al.,* they concluded that a congenital hypoplastic arch of the atlas (C1) caused spinal stenosis (in two of the Chinese patients included in their study) and predisposed these individuals to spinal cord compression related to normal degenerative changes of the spinal canal[61].

Martich *et al.,* studied the occurrence of a hypoplastic C1 in children aged two to three years with Down syndrome. The posterior arch of C1 was found to be hypoplastic in 26% of their study population of 38 children. The occurrence of this condition in C2-C5 was not evident. Their study is important as dislocation of the atlanto-occipital joint in infants with Downs syndrome is well known and is a concern that should be addressed and assessed early in the child's life[62].

3.2.4.2 Craniocervical intradural neurenteric cysts

Neurenteric cysts result from abnormal separation of the germ cell layers during the third week of embryonic development. These cysts are mostly found in the cervical region and ventral to the spinal cord from the craniocervical junction up to the level of C6. Associated bony anomalies include hemi-vertebrae, a bifid clivus and blocked vertebrae. These cysts are rare congenital abnormalities and may become symptomatic among the paediatric population[63].

3.2.4.3 Scoliosis

The rearrangement process of the succeeding sclerotomes is fairly complicated, and it is not uncommon for two adjacent vertebrae to fuse asymmetrically or to have half a vertebra absent. This will result in lateral curving of the spine[53].

3.2.4.4 Arnold-Chiari malformations

These malformations are developmental anomalies involving the brainstem and the cerebellum by which these structures are displaced into the cervical spinal canal. In children the simultaneous occurrence of hydrocephalus and or meningomyelocele may complicate the condition. It is thought that the symptoms of these malformations most often only start occurring from the ages of 30 to 50 and they may in this period be misdiagnosed as symptoms of degenerative diseases due to the presence of the syrinx in the cord[64].

These malformations are thought to occur because of the abnormal caudo-cranial proceeding growth of the cervical spine whilst the normal cranio-caudal proceeding growth of the brain persists. A growth collision occurs and this is what then causes the growth of the brain structures into the upper cervical spinal canal[64].

3.2.4.5 Klippel-Feil anomaly

Another frequent occurrence is the presence of more or less vertebrae than is normal. Patients with the Klippel-Feil anomaly (KFA) have fewer than normal cervical vertebrae. Other fused vertebrae or vertebrae with abnormal shape are also often observed with this condition, and these abnormalities are associated with other abnormalities[53].

Klippel-Feil syndrome may also be defined as the congenital fusion of two or more adjacent cervical vertebrae and it is presumed to be a result of faulty segmentation of the developing axis of the embryo during week three to eight of gestation. Persons affected by this condition are predisposed to spinal cord injury as a result of minor trauma as hypermobility of the affected cervical regions is present. Congenital urinary tract anomalies are often also associated with this condition[65].

The most common encountered radiological findings correlated with this condition are disc herniations and cervical spondylosis, especially in the lower cervical regions. Secondary degenerative changes were clustered at the levels adjacent to the fused vertebrae. Other co-existing congenital factors are cervical cord diastematomyelia and dysraphism. Patients who are suspected to have KFA prior to radiography present with short neck, low occipital hairline and limited cervical mobility[66].

3.2.4.6 Spina bifida (cleft vertebra)

This is quite often regarded as one of the most serious vertebral defects – imperfect or non-union of the vertebral arches. This condition has various subdivisions, depending of the involvement of the bony and other tissue elements[53].

3.2.4.6.1 Spina bifida occulta

Only the bony tissue is involved and the vertebral arches have not fused. The spinal cord remains in tact and the bony deficit is covered by skin. No neurological deficit is observed[53].

3.2.4.6.2 Spina bifida cystica

The neural tube fails to close; there is failure of vertebral arch formation and exposure of neural tissue. The associated neurological deficits depend on the level and extent of the lesion[53].

In some cases only the fluid-filled meninges protrude through the defective vertebral arches (spina bifida with meningocele). Occasionally neural tissue also protrudes into the sac (spina bifida with meningomyelocele) and non-elevated neural folds remain as flattened masses of neural tissue (spina bifida with myeloschisis or rachischisis). Hydrocephalus is associated with almost all cases of spina bifida cystica because the spinal cord is tethered to the vertebral column [53].

This condition can be prevented and the incidence thereof reduced by up to 70% by consumption of folic acid by the mother beginning two months prior to conception and continuously during gestation(400 µg per day)[53].

3.2.5 Prenatal detection and treatment of vertebral defects

Vertebrae can be seen and visualised at 12 weeks of gestation, and defects in the closure of the vertebral arches can be detected at this time by means of ultrasound[53].

If neural tissue is exposed (Spina bifida cystica) elevated levels of alpha-fetoprotein in the amniotic fluid can be detected by a routine amniocentesis, while elevated levels of this protein are also evident in the maternal serum[53].

Treatment of Spina bifida cystica can now be performed via *in utero* surgery at about 28 weeks of gestation. A caesarean section is performed and the defect is repaired where after the baby is placed back in the uterus. This approach is shown to decrease the incidence of hydrocephalus and also improves bowel and bladder control[53].

3.3 Cervical spinal stenosis

Cervical spinal stenosis is the narrowing of the cervical spinal canal. Stenosis may occur for various reasons including degenerative changes in the vertebra or intervertebral disc, trauma, ossification of the posterior longitudinal ligament, and cervical spondylosis[67].

A midsagittal spinal canal diameter of less than 12mm is believed to be indicative of cervical spinal stenosis[6], and is frequently observed in patients experiencing neurological symptoms related to those of cervical spinal stenosis. Torg[7] goes as far as stating that the determination of cervical spinal stenosis requires the demonstration of a sagittal diameter of the spinal canal of less than 14mm from C4 to C6.

The diameter of the spinal canal should be wider than 13mm on lateral view of x-rays, to rule out possible spinal cord damage[68]. Higo concurred with this and determined that the dividing point between normal subjects and those with developmental spinal canal stenosis was 14mm for males and 13mm for females[69]. Yet, the study by Martin found that spondylitic myelopathy occurred in eight of 21 patients, where the sagittal diameter was more than 14mm – despite the belief that such a wide diameter precludes the incidence of myelopathy[70].

Cervical spinal stenosis is a pathological condition in which the cervical spinal canal becomes narrow because of various predisposing factors. The clinical importance of identifying spinal stenosis is outlined by its occurrence amongst older individuals and the prevalence of painful symptoms associated with this condition. The narrowing of the spinal canal does not cause any symptoms *per se*, but rather when inflammation starts occurring at the site where pressure symptoms are experienced[71]. It has often been associated with degenerative changes in the anatomy of the cervical vertebral column and the related soft tissue.

Various methods have been used to visually establish the presence of stenosis - be it with CT[6,72], MRI[17,19] or plain radiographs[28,68], and Pavlov's ratio has established itself in the field of cervical spinal canal stenosis as a clear indicator of the condition[20,73]. A number of surgical techniques have been identified as a possible means of relieving spinal stenosis, and a lot of research has been dedicated in this field to improve the outcome of these surgical procedures.

Although cervical spinal stenosis is not a fatal pathology, high morbidity is prevalent in patients with the condition evident on multiple levels in the cervical vertebral column, and neglect to identify this condition can have severe consequences. The condition can be treated successfully with minimal complications.

3.3.1 Predisposition factors

3.3.1.1 Sex

The cervical spinal canal is found to be consistently narrower in females than in males[27], and the dividing line between normal and stenotic canals should be considered accordingly[69].

Hukuda and Kojima compared the body/canal ratio between males and females and concluded that the anteroposterior measurement of the vertebral body correlated highly with the size of the spinal canal in males, but not in females. The ratio was found to be significantly higher in females than in males. A significantly high body/canal ratio in males may implicate the prevalence of cervical myelopathy. Their study population was 219 patients[22].

3.3.1.2 Age

Various studies confirm that the sagittal diameter of the cervical spinal canal decreases with age[27,26,58,2]. Ageing results in degenerative causes that, when in advanced stages, can cause spinal cord compression[74].

3.3.1.3 Degenerative causes

Cervical spondylitic myelopathy is regarded as a condition where degenerative changes in the cervical vertebral bodies and intervertebral discs cause disturbances of the spinal cord by either direct mechanical compression or disturbance of the blood supply[27].

Degenerative cervical disorders mostly lead to anterior spinal cord compression, either by degenerated discs or by bony spurs at the posterior border of the vertebral body[75]. These may have a foraminal and or central distribution pattern. In the minority of cases, the spinal canal may be encroached upon from posterior by bulging ligaments, the posterior longitudinal ligament, or bony outgrowths. This often results in compression syndromes of the roots or the spinal cord[75]. Cervical stenotic myelopathy pathogenesis includes cervical spondylosis, cervical disk herniation with a narrow spinal canal and ossification of the posterior longitudinal ligament[76].

Vertebrolisthesis (movement of the vertebral bodies in relation to each other), and especially retrolisthesis in an anteroposterior direction, may lead to the movement of a vertebral body into the spinal canal with subsequent stenosis of the canal[28]. Degenerative changes at lower cervical segments predispose individuals to increased mobility and spondylitic changes at the level of C3-C4[77].

Gore *et al.,* found in their study that at age 60-65 years, 95% of men and 70% of women showed at least one degenerative change on their x-rays, and the highest correlation of decreased sagittal cervical spinal canal dimension was with the size of posterior osteophytes at the level of C5-C6[78]. Pain is more likely to develop in persons manifesting with degenerative changes at this level[79].

3.3.1.3.1 Vertebral osteophytes

Severe degenerative processes may lead to osseous changes of the vertebral bodies i.e. osteophytosis. Osteophyte formation often leads to stiffening of the vertebral column[80]. Development of posterior osteophytes on vertebral bodies may have the same effect as vertebrolisthesis[28], depending on the severity of the osteophytosis. Cervical spinal disorders like spondylitic radiculopathy are often related to osteophyte formation[37].

If the sagittal diameter of the cervical spinal canal is less than 16mm, osteophytes along the posterior border of the vertebral body may produce cervical radiculomyelopathy, although the spinal cord may escape compression. When the diameter is less than 13mm, it can be said with great certainty that these posterior osteophytes will compress the cervical cord and roots[81]. Occurrence of cervical vertebral osteophytes markedly increases with advancing age[82].

The study by Taitz[29] on the South African Negroid population indicated clearly that there was a marked difference between the occurrence and distribution of osteophytes in the cervical region between South African blacks and whites. Osteophytes occurred significantly less in the black population than in the white, and in the black population there was a greater tendency for osteophyte occurrence either on the vertebral bodies or on the apophysial joints, but not on both areas. The study showed no significant differences between males and females, and although a difference is described between a “younger” group (30-59 years) and an “older” group (60+ years), the age of osteophyte onset is not clearly established.

Also, occurrence of osteophytes and age of onset is of anthropological importance as development of osteophytes on the vertebral skeleton is used as a general indicator of age at time of death[38].

3.3.1.3.2 Ossification of the posterior longitudinal ligament (OPLL)

Ossification of the posterior longitudinal ligament is a well recognised cause of spinal stenosis and myelopathy in the elderly[42] and in various other population groups[41,42]. OPLL also causes encroachment of the spinal canal and contributes to a narrower sagittal spinal canal diameter[30] with subsequent compression of the spinal cord[39].

Neurological deficits associated with OPLL are associated with the size of the spinal canal[40]. Patients with OPLL may present with acute spinal cord injury after minor trauma[41].

Ossification of the posterior longitudinal ligament causes compression of the spinal cord by protruding into the spinal canal and onto the spinal cord. In a case study by Maezawa *et al.,* (1996) they reported a female patient with a 50% spinal canal compromise due to this condition[83], and Sato and Turu in their study concluded that in symptomatic cases of OPLL the sagittal diameter of the cervical spinal canal was significantly narrower than their asymptomatic counterparts. They calculated that the average ossification rate was 0.67 mm anterioposteriorly per annum[84].

Computed tomography to show ossification of the posterior longitudinal ligament has shown to give more detail about the stenotic spinal canal and should be examined when operative intervention is considered.

3.3.1.4 Shape of the spinal canal

Many authors agree that the shape of the spinal canal may greatly influence the occurrence of pathological conditions[24] such as spinal stenosis[10] and predisposition to spinal cord injury with enough trauma[25], with the described trefoil shape being most problematic[10].

Figure 4. *Cervical vertebra with trefoil shaped canal*

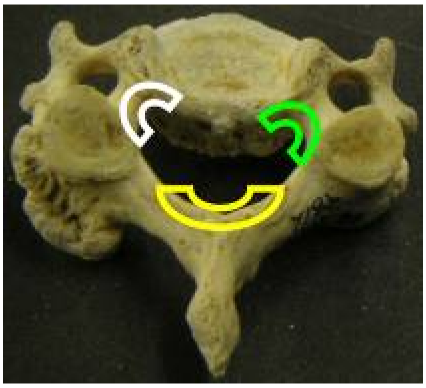


Figure 5. *Cervical vertebra with markers indicating trefoil shape (compare to Figure 6)*

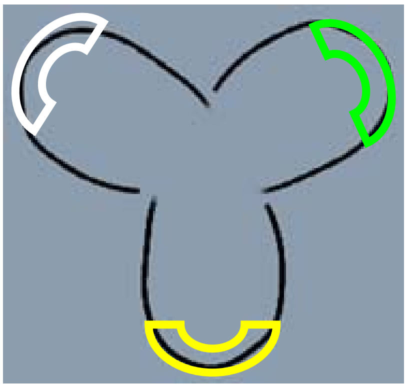


Figure 6. *Drawing of exaggerated trefoil shape with markers (for comparison with Figure 5)*

Shidahara's study in 1990 showed that in patients with developmental cervical spinal stenosis, the trefoil spinal canal shape was found more frequently than in the control group[10].

3.3.1.5 Congenital causes

Frost *et al.,* (1999) described an adult Down syndrome patient with tetraplegia and sub-acute progressive respiratory failure. The patient's death was attributed to severe degenerative joint disease of the cervical spine with osteophyte formation and severe stenosis of the spinal canal[12]. In patients with congenital spinal canal stenosis, degenerative changes at adjacent vertebra often result in long-term morbidity[85].

Achondroplasia in patients is often associated with spinal stenosis. Cervical spinal stenosis frequently involving the craniospinal junction is more commonly found in children whilst the thoracolumbar stenosis more often favours adults[60].

Developmental cervical spinal stenosis causes a reduction of the dimensions, especially in the sagittal plane of the canal, and usually becomes symptomatic in adults when myelopathy results from spinal cord compression due to small osteophytes or hyperextension injury without the presence of fracturing or dislocation. Although data is not readily available for prevalence and incidence, it does occur in the paediatric population[11].

3.3.2 Symptoms of cervical spinal stenosis

The narrowing of the spinal canal does not cause any symptoms *per se*, but symptoms are experienced when inflammation starts occurring at the site of pressure. There is a direct correlation between the dimensions of the spinal canal and its association with neurological consequences after trauma[23].

Frequent symptoms include chronic neck pain and cervicogenic headaches[76,86]. Patients with cervical compressive myelopathy sometimes exhibit localised girdle sensation in the mid trunk. This may be caused by severe compression of the ventral midline structure of the spinal cord[87].

3.3.2.1 Axial

Axial symptoms present in cases of severe cervical spinal canal stenosis include: neck and/or shoulder stiffness and neck pain[88], hand clumsiness and cramping, as well as sensory loss or abnormal reflexes. In severe cases pain can be chronic.

3.3.2.2 Motor and somatosensory

Prolongation of motor and central sensory conduction times have been observed in patients with cervical myelopathy. These were more pronounced in the group of patients with multiple level spondylitic stenosis of the spinal canal[89].

3.3.2.3 False localising sign

A false localising sign may be observed in patients with severe cervical spinal cord compression in the midline ventral structure of the cord. These patients experience a localised girdle sensation, described as a vague or burning sensation over approximately three or four dermatomes from the level of T3 to T11[87].

3.3.3 Diagnosis

3.3.3.1 Magnetic Resonance Imaging (MRI)

Spinal stenosis may be classified in accordance with spinal cord compression by means of magnetic resonance imaging. In a grading system used by Muchle *et al.,* (1998) cervical spinal stenosis was classified into the following categories: 0 = normal; 1 = partial obliteration of the anterior or posterior subarachnoid space; 2 = complete obliteration of the anterior or posterior subarachnoid space and 3 = cervical cord compression or displacement[90].

It is important to note that artefacts related to MRI can alter the apparent shape of the spinal canal and may also possibly exaggerate the extent of spinal stenosis observed in patients with cervical spondylosis[91].

3.3.3.2 Computed Tomography (CT)

A study by Debois *et al.,* (1999) measured amongst others the sagittal and transverse diameters of the bony spinal canal and the cross-sectional area of the spinal canal in an attempt to establish a relationship between spinal canal diameters and neurological symptoms associated with soft disk herniation. They concluded that a narrow sagittal diameter increased the neurological symptoms in patients with soft disk herniation. They also found that in patients that experienced soft disk herniation, the bony spinal canal was narrower, and the cross-sectional area of the canal smaller[92].

3.3.4. Treatment

3.3.4.1 Surgical

The goal of surgical intervention is to relieve the pressure on the spinal cord, and to subsequently relieve the spinal stenosis.

3.3.4.1.1 Cervical laminoplasty

During a meta-analysis by Ratcliff and Cooper, the authors of papers reported a mean of between 55% and 80% of patients improving after laminoplasty. They concluded that there was no evident neurological outcome difference between the various laminoplasty techniques. Cervical alignment was reportedly worse in about 35% of cases. Patients also have a tendency to develop severely decreased cervical range of motion, similar to that experienced in laminectomy and vertebral fusion[67]. Axial symptoms were not significantly influenced, developed or resolved by cervical laminoplasty[88].

A method of laminoplasty (Kurokawa's procedure) has been evaluated by Martin-Benlloch *et al.,* (2003). The cervical spinal canal was expanded by means of splitting the spinous process of the vertebra in order to increase the canal/body ratio. This method yielded successful results, but a decrease in range of motion was still noted[93].

Vatsal *et al.,* (2003) suggested a laminoplasty technique that incorporates the spinous process of the vertebra into the neural arch. This method eliminates the use of foreign material such as free grafts, metallic and non-metallic foreign materials used in other laminoplasty techniques[94].

3.3.4.1.2 Anterior cervical corpectomy and fusion

In an evaluation of graft and plate complications for anterior cervical corpectomy and fusion, fusion at two levels has a mere a 6% failure rate, whilst a three level fusion has a 71% failure rate, according to a study done by Sasso *et al.,* in 2003. This procedure was attributed to spondylosis, stenosis and ossification of the posterior longitudinal ligament[95].

They recommend that simultaneous posterior fusion should also be considered in such patients[95].

Other surgical techniques include foraminotomy, laminotomy, medial facetectomy, anterior cervical discectomy and fusion.

3.3.4.2 Non-surgical

Non-surgical treatment often does not treat the stenosis but rather temporarily relieves pain associated with the stenosis[96].

3.3.4.2.1 Medications

Medications would include non-steroidal anti-inflammatory drugs to reduce the swelling and analgesics to relieve pain[96].

3.3.4.2.2 Corticosteroid injections

These are used to reduce swelling and acute pain that may radiate to the extremities. They are not often administered and usually not more than three times in a six month period[96].

3.3.4.2.3 Rest

Rest or restricted activity is often advised, depending on the nerve involvement and the extent of the pathology[96].

3.3.4.2.4 Physical therapy

Exercises help stabilise the spine, increase flexibility and increase endurance[96].

3.4 Pavlov's Ratio

Pavlov's ratio is defined as the ratio between the sagittal diameter of the spinal canal and the sagittal diameter of the corresponding vertebral body[20]. The ratio eliminates errors related to magnification, which are frequently observed when using lateral x-rays for measurement[73].

This ratio is currently used as a universal indicator of cervical spinal canal stenosis, in spite of the fact that differences between race and sex have been reported[4].

In normal individuals the ratio is close to one and where the ratio is less than 0.85 stenosis is said to be present. A ratio of below 0.8 is believed to be a significant risk factor neurological injury, and establishes a canal to be congenitally narrow. Absolute or relative stenosis (smaller than 10mm and 10 - 13mm respectively) are risk factors for radiculopathy, myelopathy or both due to trauma or relatively minor spondylosis pathology[20]. Suspicion of cervical spinal myelopathy is supported by the finding of a spinal canal sagittal diameter less than 11mm and a Pavlov index of less than 0.8[21].

Yue *et al.*, [73] found that the ratio is significantly smaller in patients with cervical spondylitic myelopathy than a non-spondylitic (0.72 +/- 0.08), non-myelopathic population (0.95 +/- 0.14). And, as patients with congenital cervical spinal canal stenosis have an increased likelihood of developing cervical spondylitic myelopathy, the ratio is said to possibly predict development of this condition[73].

However, studies done on different population groups yielded contradicting results in terms of the validity of the application of the Pavlov ratio. Lee *et al.,* (1994) concluded from their study on adult Koreans that the canal/body ratio is a more reliable method for determining cervical spinal stenosis or predicting cervical spinal cord injury, than directly measuring the sagittal diameter of the spinal canal in this area[3], while a study done on a Japanese study population comparing the vertebral body/canal ratio between males and females concluded that the anteroposterior measurement of the vertebral body correlated highly with the size of the spinal canal in males, but not in females. A significantly high body/canal ratio in males may implicate the prevalence of cervical myelopathy[22].

However, a study by Prasad *et al.,* (2003) found however that there was a poor correlation between Pavlov's ratio and the space available for the spinal cord, and therefore concluded this ratio cannot be used as the only method to predict the changes in the sagittal plane of the cervical spinal canal[19].

An index for the spinal canal/vertebral body ratio for the paediatric patient has been established by Robinson, Northrup and Sabo, and indicated that the ratio decreases consistently through to the adult groups. Their index can be used to determine the development of early disease processes[57].

3.5 Cervical surgical techniques

Richter, Kluger and Puhl recommend that in the case of cervical spinal stenosis with myelopathy surgery should be considered in the early stages of the condition[97]. Surgical approaches for cervical osseous pathology where the spinal canal is narrowed or obstructed include laminoplasty, laminectomy and anterior approaches whereby the entire vertebral body is removed. Anterior decompression is recommended for young persons[98,99] as well as for individuals with predominantly anterior pathology or ossification of the posterior longitudinal ligament with kyphosis[98,100].

Heller *et al*., [101] undertook an independent matched cohort study to compare the clinical and radiographic outcomes between laminectomy with fusion and laminoplasty in the treatment of multiple level cervical myelopathy. Their results showed that within their study population of 26 no complications occurred in the laminoplasty group whilst their matched laminectomy counterparts had nine patients out of 13 with complications. These included progression of the myelopathy, non-union, developed kyphotic alignment, deep infection, instrumentation failure and subjacent degeneration requiring further surgery. They advise that laminoplasty may be the superior method when compared to laminectomy with fusion as a posterior approach[101]. Praharaj, Vasudev and Kolluri confirmed that cervical expansive laminoplasty is a simpler and safer alternative to anterior laminectomy and that it provides favourable spinal cord decompression[102] and cervical spine stabilisation[102,103].

The advantages of laminoplasty over laminectomy are that (a) the spinal cord retains its osseous protection, (b) spinal cord invasion by scar tissue is limited and (c) spinal stability is maintained[103,104].

3.5.1 Laminoplasty

3.5.1.1 Laminoplasty Techniques

There are three basic variations in laminoplasty: French door or midline, single open door and double-door techniques[105]. Patel, Cunningham and Herkowitz concluded that none of the methods are superior to another and that satisfactory clinical results are obtained irrelevant of the technique used[105].

Midline laminoplasty involves the splitting of the bifid spinous process and placement of a graft between the two halves of the spinous process to enlarge the spinal canal. Single open door relates to the hinge like mechanism of expansive laminoplasty whereby one of the lamina is opened and the other lamina is left intact to have the spinous process attached to the intact lamina like an opened door[106]. Usually a titanium plate or graft is inserted into the opened lamina to keep it from closing and by so doing decompresses the spinal canal and the spinal cord. Double door laminoplasty differs from single open door laminoplasty in that both the laminae are opened[106] and grafts placed on both sides of the spinous process to keep the spinal canal closed but enlarged. The optimal widening of the anteroposterior diameter of the spinal canal is considered to be over 4mm[106].

Various spacers, grafts and screws are used to maintain the widened canal after laminoplasty: Hydroxyapetite spacers with titanium screws have been proven to yield sufficient fixation[107]. In a technique described by Vatsal *et al.,* [94] multiple level canal stenosis was treated by means of the incorporation of the spinous process into the neural arch. This method excludes possible complications caused by foreign material (metallic or non-metallic) or free grafts.

Wang *et al*., [108] describe a minimally invasive technique by which a 10mm rib allograph spacer was inserted to maintain a gap and increase the spinal canal[108] whilst Frank and Keenen proposed the insertion of titanium mini-plates that allow adequate decompression of the spinal cord and the bilateral cervical nerve roots[109].

Kawai *et al*.,[110] describes the Z-shaped laminoplasty technique designed by Hattori in 1971. The procedure involves the grinding down of the laminae with an air drill and then making a z-shaped cut into the thinned laminae without the excision of the laminae. The procedure is proposed to decompress the spinal cord whilst clinically maintaining stability of the spine[110].

3.5.1.2 Indications for laminoplasty

Seichi *et al*., [111] conclude that laminoplasty, in their case double door laminoplasty, is a reliable procedure for the treatment of patients with cervical stenotic myelopathy[103,111]. Laminoplasty provides a safe alternative to multiple level laminectomy or anterior approaches[102] for patients suffering from multilevel spinal stenosis[105] and myelopathy[97].

In the absence of pre-operative kyphosis, laminoplasty proved to be the preferred surgical intervention when compared to corpectomy, as multilevel cervical myelopathy patients retrospectively tend to require lower levels of pain medications after laminoplasty[112]. Cervical expansive laminoplasty has also been indicated as an alternative to anterior laminectomy and fusion in cases of myeloradiculopathy and myelopathy due to multi-segmental cervical spondylosis and ossified posterior longitudinal ligament[102].

If the cervical lordotic curve is well preserved, posterior decompression such as laminoplasty is suitable for older individuals presenting with ossification of the posterior longitudinal ligament or spondylostenosis[98].

Jansen[86] suggests dorsal laminoplasty for relieving cervicogenic headaches. His study shows that when degenerative diseases are present that narrow the spinal canal the headaches may occur because of irritation of the dura that contains nociceptive receptors. Decompression of the spinal canal relieves the irritation on the dura and then subsequently the cervicogenic headaches. This condition has previously been successfully treated by anterior decompressive surgery[86].

3.5.1.3 Recovery and complications after laminoplasty

Recovery after the procedure is between 50% and 70% regardless of the laminoplasty technique that was used with no technique being superior above another. Good to excellent results can be expected over the long term if patients are correctly selected for the procedure[105].

In the study by Vatsal *et al.,* [94] they found that the sagittal diameter of the spinal canal was increased by 4.2mm after incorporating the spinous process into the neural arch. Bony fusions were observed in the gutters after six months. Patients showed improvement in both sensory and motor function[94]. The study done by Tomita *et al.,*[113] yielded similar results.

Laminoplasty in both young and elderly patients shows promise where multisegmental spinal canal stenosis is present. In elderly patients the predictive factors for the clinical outcome include the severity of the stenosis and the duration of the symptoms. Improvement of the disability in elderly patients depends on intervention before irreversible changes to the spinal cord occur[114]. Improvement can be contributed not only to the enlargement of the spinal canal and the subsequent decompression of the spinal cord but also to the improved circulation within the spinal cord and nerve roots[115].

Complications often associated with laminoplasty are temporary nerve root deficit[105], closure of opened laminae[105], decreased range of motion in the neck[105] and axial pain[105]. Detachment of the posterior cervical muscles during expansive laminoplasty is thought to possibly contribute to axial neck pain postoperatively and kyphosis[108].

Takagi *et al*., [116] report a rare case where a patient that underwent successful laminoplasty experienced T1-2 intervertebral disc herniation 11 years later. The herniation was attributed to the mechanical stresses following the laminoplasty which may directly have affected the T1-2 disc[116].

Development of spinal deformities such as kyphosis and instability after laminectomy are major clinical problems[117]. Shikata *et al.,* [117] conclude from their study on adolescents and children undergoing spinal surgery for spinal cord tumours and other diseases that laminoplasty in combination with posterolateral fusion may prevent the development of these deformities[117].

Praharaj, Vasudev and Kolluri[102] report a patient showing deterioration post-operatively and development of Brown-Séquard features as a result of under-riding of the lamina on the hinged side. Another patient manifested with paraesthesias after the procedure. They also report on one instance where follow-up CT scans showed evidence of "closing of the door", although the patient remained asymptomatic thereof[102].

3.5.1.4 Limitations of laminoplasty

Suda *et al.,*[118] showed that surgical results of expansive laminoplasty can be severely altered by cervical misalignment. They determined that one of the highest risk factors for poor surgical outcomes is kyphosis of more than 13 degrees, the other being changing signal intensity on an MRI[118].

Posterior decompressive approaches in younger individuals with or without a lordotic curve and older individuals with kyphosis may yield them susceptible to early neurological deterioration or may fail to significantly improve the patient's condition[98]. Also, posterior decompression of the ossified posterior longitudinal ligament may promote more rapid progression of the structure[98]. Maiuri *et al*., [119] suggest that decompressive laminectomy should be reserved for patients where the ossification of the ligament extends to four or five levels and at a level above C3.

It should be considered that performing cervical surgery may have other complications. Lee *et al.,*[120] describes the rare occurrence of a 71 year old patient developing pulseless electrical activity during laminectomy. Hypothermia triples the incidence of major cardiac events, with the outstanding occurrence in this case being a low nasopharyngeal temperature of 31 degrees Celsius during the procedure[120].

The efficacy of expansive laminoplasty can be restricted by different factors such as irreparable spinal cord degeneration[103]. Frank and Keenen noted that accepted laminoplasty techniques may limit the ability to decompress cervical nerve roots and stenosis may re-occur because of the failing of the constructs[109].

3.5.1.5 Concluding remarks on laminoplasty

Laminoplasty is a safe alternative to other procedures such as laminectomy and anterior decompression with corpectomy and or fusion. Advantages like limitation of scar tissue movement into the spinal canal and spinal cord, the maintained spinal stability and the retained osseous protection of the spinal cord makes it a popular method for expanding the cervical spinal canal in cases of spinal stenosis and myelopathy amongst others.

Various factors may limit the efficacy of the procedure but even in cases where complications are found the vast majority of patients do report improvement, even if only to a small extent. The age of the patient and severity of the pathology is of the utmost importance when considering the appropriate surgical procedure to relieve symptoms and improve quality of life and correct patient selection will yield very high clinical success.

3.6 Imaging techniques of the cervical spinal canal

3.6.1 Introduction

Various methods of imaging are available to visualise the spine in different positions and from different angles. Many techniques are used to obtain different results to exclude or confirm a particular diagnosis and determine an appropriate treatment. Pre-operative imaging may be used as a guide for the course of action that is to be taken whilst post-operatively it provides evidence of the efficacy of the procedure. It is however important to note that in spite of the differences between the methods they compliment each other and their roles are as counterparts and associates rather than separate entities for separate purposes.

Imaging techniques should be carefully selected for patients as not all patients are physically fit to undergo certain imaging, and radiation exposure should be kept to a minimum if at all possible. Whilst it is an exciting prospect to confirm a suspected diagnosis, care should be taken not to injure the patient by moving them or by forcing flexion and extension for appropriate film series. A different imaging technique should rather be considered as alternative to moving the patient in a compromising situation.

3.6.2 Radiography (X-ray)

An adequate cervical spine series, especially in a trauma situation includes radiographs showing three views: true lateral x-ray showing C1-C7 as well as the C7-T1 junction, open mouth odontoid view x-ray and an anteroposterior x-ray.[121]. Whilst some spinal dislocations or fractures may be missed because of film misinterpretation, it often occurs because of lack of an adequate series of film[122,123].

It is also extremely important to note that due to radiation, pregnant women should not be radiographed at all. Also, in children younger than nine years who are conversant, alert, without neurological deficit and who have no painful distracting injury or midline cervical tenderness and are not intoxicated, x-rays may not be necessary to exclude cervical spinal injury and it is not recommended. Where the child is not alert or non-conversant or manifests with painful cervical midline tenderness or distracting injury or has unexplained hypotension, anteroposterior and lateral view x-rays are recommended[124].

Imaging assessment is of the utmost importance where spinal cord injuries are suspected for children and the three views should be routinely indicated[125], provided that the above criteria are met[124].

3.6.2.1 Lateral X-ray

Arguably the obvious purpose of lateral x-ray is firstly to determine the alignment of the spine[68]. Finer details can be established on closer observation. The diameter of the spinal canal should be wider than 13mm on lateral view[68] to rule out possible spinal cord damage.

In 1998 Sasaki, Kadoya and Iizuka[27] conducted a study on the cervical spinal canal of a Japanese study population consisting of 1000 patients on lateral radiographs. The sagittal diameter of the cervical spinal canal was measured and results were accurately described up to one tenth of a millimetre. Hashimoto and Tak[126] describe a method to determine the true sagittal diameter of the cervical spinal canal by using a midline perforated ruler on normal x-rays. They used C3-C7 for measurements. Their results correlated well with dried specimens[126].

Vatsal *et al.,* [94] employed lateral radiographs to assess their laminoplasty procedural results in terms of canal diameter, bony union and cervical spine alignment[94].

3.6.2.2 Open mouth X-ray

The major purpose for this x-ray is to examine the odontoid process and its dimensions. The overlying teeth at the level of the odontoid process create artefacts that may create the idea of a fracture, and the teeth should be kept out of the field or removed from it if possible. Fractures of the dens may have to be confirmed by CT scans. The dimensions of C1 should also be studied in order to exclude a possible fracture that may be indicated by any form of asymmetry[68].

3.6.2.3 Anteroposterior X-ray

Cervical spine heights should be approximately equal on the anteroposterior view x-ray. Spinous processes should be in the midline as deviation from the midline may be indicative of a facet dislocation[68].

3.6.2.4 Limitations of X-Ray

Very often spinal fractures are missed on plain radiographs[127,72] and if any question should arise about an abnormality or suspected condition computed tomography scans (CT-scans) should also be done[68]. Drudi *et al.,*[128] agree that a suspected fracture on radiograph should be followed up by a CT-scan of the area.

3.6.3 <u>Magnetic Resonance Imaging (MRI)</u>

MRI is an examination that is indicated for suspicion of a neurological lesion, especially of the bone marrow. Ligament lesions may be missed and should systematically be searched for using dynamic imaging[129]. MR imaging may prove very useful in demonstrating soft-tissue injuries such as disc herniation, nerve root impingement, haemorrhage and direct spinal cord imaging[130].

MRI should routinely be performed in all children with cervical spinal cord injuries without radiographic abnormalities[125]. These injuries can be accurately evaluated with MRI which will show the abnormality and could also help to determine the prognosis[131].

3.6.3.1 Limitations of Magnetic Resonance Imaging

Problems with MRI include the fact that Fourier transforms are used to process the MR signal and truncation artefacts may occur that may alter the intensity, shape and anatomical detail in the spine[132]. Suda *et a l*[118] established from their study that a changed MRI signal intensity is a risk factor for poor surgical outcome in patients that are considered for laminoplasty[118].

MRI is not indicated as the diagnostic method of choice in trauma situations. This is partly because it is not always readily available and it takes a long time to perform a scan, but also because resuscitation equipment with metal parts may not work properly in the magnetic field generated by the MRI[68].

3.6.4 Computed Tomography (CT)

Computerised tomography (CT) has been described as a sophisticated and non-invasive procedure to study the nerve root tunnel and vertebral column[47]. A large number of studies have been done on the spinal canal using computerised tomography. Thin section CT imaging seems to be described the most and its uses in studies measuring sagittal and transverse diameters, as well as the cross-sectional area of the spinal canal are well documented[48,25,49]. Sections at the level of the pedicles are often used to clearly view of the spinal canal, vertebral bodies and dural sac[50].

Vertebral abnormalities have been reported to be optimally assessed with CT, and the application of three-dimensional imaging and multi-planar reformation lead to enhanced diagnostic information evident on cross-sectional images[45]. O'Brien *et al.,*[133] used computer assisted morphometric analysis on pre- and post-operative CT scans to determine the dimensions of the spinal canal.

Kligman, Vasili and Roffman[134] reported that in five patients out of their 26-patient study population CT-scanning revealed cervical spinal injury that went unnoticed on x-rays and during clinical examination[134]. Scanning is the most efficient technique for the detection but also for formal elimination of an injury[129].

3.6.4.1 Limitations of Computed Tomography

Computed tomography may be limited for study purposes to determine the normal anatomy, especially in the cervical region since most of the CT procedures are performed on patients with cervical pathology[49]. Also, changing the scan angle by more than 10 degrees will alter the values of the anteroposterior and cross-sectional area measurements and patterns significantly. The transverse diameter however, seems to remain very little changed[135].

3.7 Geometric Morphometry

3.7.1 Introduction

Geometric morphometry enables us to understand the evolution of shapes based on mathematical modelling and descriptions[136]. It is used to define the shape of biological organisms using point coordinates (both landmark and outline coordinates), in two or three dimensions, as data[137] and studying the shape variation of landmark configurations[138]. Geometric morphometry also encompasses multivariate statistical tests on group differences and other effects on the configuration of landmark points, and definitive description of such effects[139].

With regards to medical imaging, landmarks can be defined as points with an anatomical meaning, and can as such be compared between images of the same anatomical region[140].

Shape is primarily defined with properties of coordinates that are independent and unaffected by scale, location and orientation[138], and it should for the purpose of this study be stated that these properties are not taken into account when determining shape.

The use of coordinates enables visualisation in plots, of shape and changes of shape in three dimensional organism spaces[137]. Linear measurements to determine shape and the change thereof are limited in that it relies on multivariate experience and familiarity with the particular study subject[137].

Although distance measurements, such as length, height and width contain information about size and shape, they do not contain the relative location of every point in space, i.e. the geometry of the form. However, the coordinates of specific landmarks (points on an organism) retain all info on geometry and distances[137].

Mathematical spaces that are used for the statistical study of shape variation start with the assumption that by recording the coordinates of landmark positions on an organism, the information on shape has been captured[141]. Coordinate data contain information that is adequate for computation of a mathematical index that can possibly be proposed to describe landmark positions relative to one another[142].

For small ranges of shape variation, there is essentially only a single average shape per sample, but there are many varied calculations for determining that average[138]. Very often the Procrustes distance (approximately the square root of the sum of the squared differences between the positions of the landmarks in two optimally superimposed configurations at centroid size[137]) between two mean shapes, is the pivotal statistic for testing for significant difference between the shapes. Procrustes distance provides a measure of coincidence of two point sets - {xi} and {yi} with i =1[142].

3.7.2 Thin-Plate Spline

Thin-plate spline is a function that maps all points in the physical space of the reference onto corresponding points in the space of the individual specimen, based on the physical properties of a thin sheet of metal[142]. It models the form taken by a metal plate that is constrained at some combination of points and lines, and is otherwise free to adopt the form that minimises bending energy[137].

Thin plate spline image deformation is a landmark-based method consisting of matching, exactly, two sets of corresponding landmarks, by using two thin-plate splines and interpolating throughout the plane to enable construction of the warped image[140].

The only information used for computation of the thin-plate spline is the location of the landmark, and the resultant transformation grids are a means of expressing relative landmark displacement and enable one to visualise all possible differences in shape that can alter the landmark positions[142]. Thin-plate spline deformation grids allow visual amplification of changes in shape that would be hardly recognisable and difficult to describe with traditional approaches[143].

The spline gives a visualisation of any pair of forms in shape space as a Cartesian deformation taking one form to another. It supplies visually the direction of shape space as the deformation of the mean form into another form, some Procrustes distance along that direction or the opposite direction[138].

However, it has to be noted that, when using thin-plate spline, shape differences that involve a landmark pair that are close together, will be weighted heavily compared to shape differences involving larger regions of separation[138].

3.7.3 Relative Warp Analysis

Relative warps are principal component analyses (eigenanalyses) of a distribution of shapes in terms of either the Procrustes distance or some power of bending energy[142]. Each relative warp, as a direction of change of shape about the mean form, can be interpreted as specifying multiples of one single transformation that can often be drawn out as a thin spline[137].

Relative warps are often expressed in terms of landmark displacement. They may be visualised as a transformation grid showing deformations of the physical space of a reference configuration, by expressing the relative warp as a thin-plate spline[142].

There are methodologies that consider statistical inference in terms of shape variables, including principle warp analysis. But, interpretation from these analyses accounting for landmark variable transformation to shape landmarks is not always easy. It may be helpful to discard original variables that convey little information regarding shape and size[144].

3.7.4 Software programs used for geometric morphometry

Various software programs have been specifically designed and developed to streamline morphometrics. These include image acquisition and quantative data analysis[145]. Geometric morphometrics can be two- or tree dimensional[137] but for purposes of this study two dimensional data will be explored. Most programs available for data analysis are able to interpret and manipulate data input from digital media such as digital photographs. This media is acquired for morphometrics to enable measurements and landmark coordinates[146].

3.7.4.1 Imagina

Imagina is one such a program developed for morphometric analysis. It is able to extract coordinates for landmark data and determine distances between landmarks and it has routines able to obtain shape from the landmark data. Imagina also interfaces with programs of other authors such as tpsRw, tpSpline (replaced by tpsSplin) and GRF-ND[145].

3.7.4.2 tps-Series

tpsDig is a program used for digitising landmarks and outlines for geometric morphometric analysis. tpsSplin (thin-plate spline) is used to compare pairs of specimens by displaying a D'arcy style transformation grid based on a thin plate spline, while tpsRelw performs a relative warp analysis corresponding to a principal component analysis of variation within a sample. It displays a plot of relative warp scores and a window for visualisation displaying the estimated shape for arbitrary points in the ordination. All these programs were designed by FJ Rohlf[147].

3.7.4.3 IMP (Integrated Morphometrics Package)

IMP (integrated morphometrics package) is a compiled set of software tools that carry out various tasks related to display and analysis of two dimensional landmark-based geometric morphometric data[148].

3.7.5 Application of geometric morphometry

The focus of morphometrics is mainly upon the quantative analysis of biomedical shape variation. However, where in the 1990's it was focused on medical image analysis, it is now mainly driven by research demand in human variability, physical anthropology, primatology and paleo-anthropology instead[149]. Non-traditional geometric morphometric methods have been widely applied within biological sciences, especially anthropology, with its strong history of measurement of biological form[150].

Size variations among organisms are usually associated with variations in shape[151]. Static allometry reflects the variation among individuals within a population and age class[151]. The analysis of closely related groups such as populations often implies comparison of very similar shapes, differing only slightly in relative landmark displacement[143].

As such, geometric morphometry has been applied to various fields of study including clinical medicine[152], anthropology[153], entomology[154] and zoology[155] amongst others.

Specifically relating to this study, O'Brien *et al.,*[133] used computer assisted morphometric analysis on pre- and post-operative CT scans to determine the dimensions of the spinal canal.

3.7.6 Importance of application of geometric morphometrics in determination of the shape of the cervical spinal canal of the South African Black population

Very few studies have been done to determine the changes in the cervical spinal canal that occur with increasing age such as change of the shape of the canal.

The shape of the spinal canal has mostly been studied in the lumbar region[33,34] and as such leaves opportunity for study and definition in the cervical region, specifically in the South African black population where no study has yet been undertaken to determine the shape of the cervical spinal canal.

As size variations among organisms are usually associated with variations in shape[151], it is important to determine the average shape of the cervical spinal canal, as well as to explore the possibility that the shape of the canal changes with age and to what extent these changes occur. Also, because the cervical spinal canal is found to be consistently narrower in females than in males[27,4], sexual dimorphism in the shape of the canal should also be investigated.

3.8 Results from previous studies on different population groups

Hashimoto and Tak describe a method to determine the true sagittal diameter of the cervical spinal canal by using a midline perforated ruler on normal x-rays. They used C3-C7 for measurements and their results yielded a lower limit of 10 mm and an upper limit of 17 mm. Their results correlated well with dried specimens[126].

Okada *et al.,* determined from MR-imaging that the minimal transverse area of the spinal canal was 236.1 mm^2 measured at the level of C4. They also measured the transverse area of the spinal cord (85.8 mm^2 at C4/C5) and determined that a significantly higher ratio of canal to spinal cord at C3 was observed in patients with cervical spondylitic myelopathy[156].

Sasaki, Kadoya and Iizuka[27] determined that in the normal adult Japanese adult (over 15 years of age) the measurements were as follows:

Vertebra Level	Mean sagittal diameter (mm)
C1	21.0 +/- 2.2
C2	18.0 +/- 1.7
C3	15.8 +/- 1.5
C4	15.2 +/- 1.5
C5	15.3 +/- 1.5
C6	15.7 +/- 1.5
C7	15.9 +/- 1.4

Table 1. *Sagittal dimensions of the adult Japanese cervical spinal canal*[27]

The smallest diameter was measured at C4, but with no significant difference between C4 and C5. Males had significantly larger diameters than did females and younger individuals also had greater diameters than did their older counterparts[27].

In a study by Lee *et al.,*[3] measuring mid-sagittal spinal canal diameter and the and the ratio of the cervical canal to body ratio in adult Koreans, results revealed that sagittal canal diameter between C3 and C7 were 13.2 +/- 1.3 mm (males) and 13.1 +/- 2.6 mm (females). Than cervical canal to vertebral body ratio was 0.93 +/- 0.10 mm (males) and 1.02 +/- 0.09 mm (females). Their results show that the sagittal diameter of the canal is smaller in Asians than in Whites, but that no racial differences exist when comparing the canal/body ratio. They conclude that the ratio method is more reliable for determination of spinal stenosis or prognosis of cervical spinal cord injury than is direct measurement of the spinal canal.

Prasad *et al.,* concluded from their study that Pavlov's ratio could only be moderately correlated with the area of the cerebrospinal fluid column and the spinal cord. The highest correlation was observed at the level of C5 (0.31). The highest correlation of the ratio with the spinal cord was observed at C4 (0.21) but the correlation was around zero. They conclude that Pavlov's ratio cannot be solely relied on to predict cervical spinal canal plane area changes on a particular plane[19].

4. MATERIALS AND METHODS

4.1 Materials

4.1.1 <u>CT-scans</u>

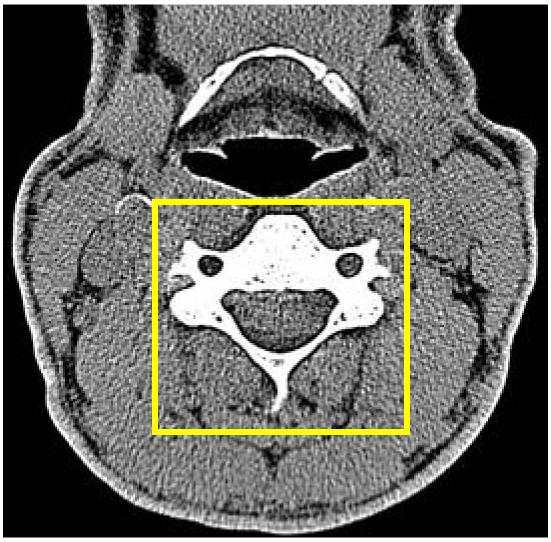


Figure 7. *CT-scan of cervical region clearly indicating dimensions of the cervical vertebra*

Figure 8. *Cervical vertebra*

CT-scans were obtained for 55 patients from Pretoria Academic Hospital, Department Radiology. They were subdivided into categories as follows:

Age Group	**Males**	**Females**
30-45	10	9
46-60	10	10
61-75	7	9
Total	**27**	**28**

Table 2. *Number of individuals in each age category for CT-scan measurements*

The CT-scans for C3 - C7 of each patient were measured using the ViewTec MedView 1.0.0.2 software program with an accuracy of 0.01mm. The software was designed specifically to analyse and process computed tomography images (DCOMDIR files). As the DCOMDIR files inherently contain a scale, the Viewtec software is able to utilize that scale to give accurate measurements, calculate angles and recreate three dimensional images.

After opening the DCOMDIR file with the program and selecting the slide of interest, the distance between the various points were measured by selecting the "Measure distance between two points" button and then clicking with the mouse pointer on the first point (e.g. midpoint on the posterior surface of the vertebral body) followed directly by clicking on the second point (e.g. junction of the laminae). The distance between the two points is automatically calculated by the software and displayed directly on the slide.

4.1.2 Skeletal material

A random sample of skeletal material was obtained from the Pretoria Bone Collection at the University of Pretoria to determine the occurrence and distribution of vertebral osteophytes in the cervical spinal canal and the incidence of ossification of the posterior longitudinal ligament also in the cervical region (C3-C7). 107 Vertebral columns were examined and were divided as follows:

Age Group	Males	Females
30-45	20	17
46-60	20	20
61-75	20	10
Total	**60**	**47**

Table 3. *Number of individuals in each age category for skeletal material examination*

Figure 9. *Cervical vertebrae – C3 to C7*

4.1.3 Geometric Morphometry

Digital photographs were taken of skeletal remains of the cervical vertebral column (C3-C7) of 179 individuals of material obtained from the Pretoria Bone Collection at the University of Pretoria and the Raymond A. Dart Collection at the University of the Witwatersrand.

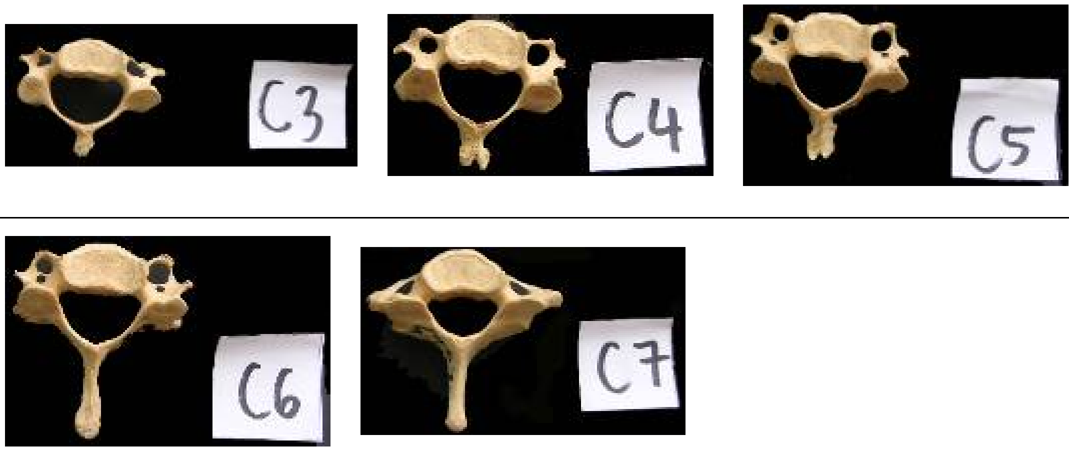


Figure 10. *Digital images of cervical vertebrae C3 to C7 used for geometric morphometry*

They were subdivided into categories as follows:

Age Group	Males	Females
30-45	30	30
46-60	30	30
61-75	30	29
Total	**90**	**89**

Table 4. *Number of individuals in each age category for digital imaging*

The tps-Programs[147] were used to analyse and compare digital data in the form of digital photographs along with the IMP (Integrated Morphometrics Package) group of programs.

- tpsDig – used for digitising landmarks
- tpsSplin – used to compare specimens by displaying a transformation grid
- tpsRelw – used to perform relative warp analysis
- IMP: TwoGroup6 – This program determines pairwise significant differences in shapes between groups using Goodall's F-test and Hotelling's T^2 test.

4.1.4 Statistics

Statistical analysis was done with Stata statistical analysis software.

4.2 Methods

4.2.1 CT-Scans

Measurements were taken on the CT-scans for C3-C7 on the level of the superior surface of the pedicles where both the anterior aspect of the canal as well as the corresponding interlaminar line is visible and measurable. The following measurements were taken:

1. Sagittal diameter of the vertebral body (anteroposterior)
2. Sagittal diameter of the spinal canal (anteroposterior)
3. Transverse diameter of the spinal canal

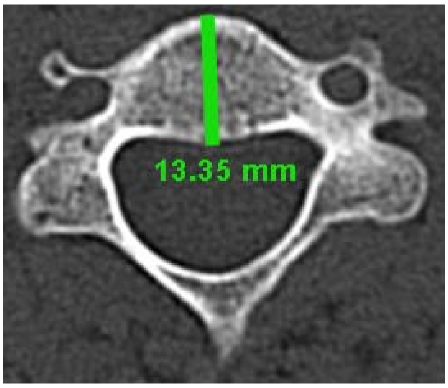


Figure 11. *Measurement 1: Sagittal diameter of the vertebral body*

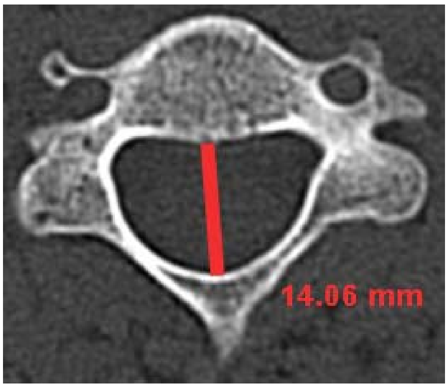


Figure 12. *Measurement 2: Sagittal diameter of the spinal canal*

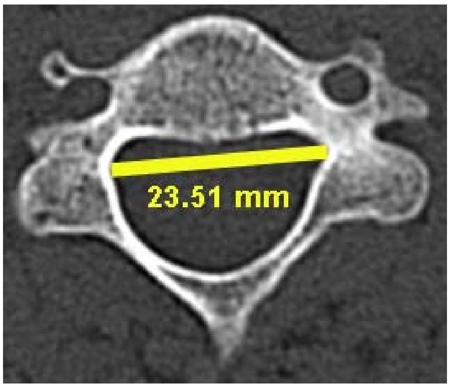


Figure 13. *Measurement 3: Transverse diameter of the spinal canal*

4.2.2 Skeletal material

Cervical vertebrae (C3-C7) were inspected on both the superior and inferior surfaces to determine the following within the spinal canal:

1. The occurrence of osteophytes
   a) On the lamina of the vertebrae
   b) On the posterior aspect of the vertebral body

2. The degree of osteophyte severity according to the scale below where:

Degree of severity	**Observation**
0	No osteophytes present or very slight bone formation towards the spinal canal, almost no intrusion into canal
1	Mild osteophyte formation, very slight protrusion into spinal canal. Does not affect shape of spinal canal
2	Severe osteophyte formation with large protrusions into the spinal canal. Osteophytes affect the shape of the spinal canal

Table 5. *Scale for classification of osteophyte severity*

3. Presence of ossification of the posterior longitudinal ligament

4.2.3 Geometric Morphometry

Digital photographs taken of skeletal material were analysed with the tps-programs

4.2.3.1 tpsDig

Each digital photo was digitised by identifying six landmarks on the spinal canal

1. Midpoint of the posterior surface of vertebral body
2. Junction of laminae of spinal canal
3. Junction of left lamina and pedicle
4. Junction of right lamina and pedicle
5. Midpoint on lamina between point 2 and 3
6. Midpoint between point 2 and 4

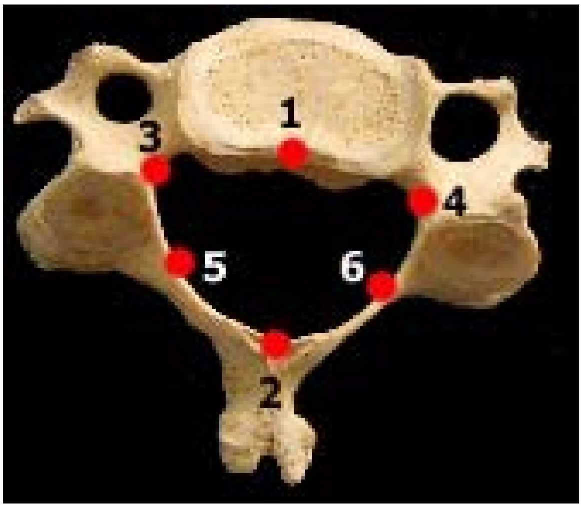


Figure 14. *Digital photograph digitised with tpsDig indicating landmarks 1 to 6*

The image is digitised by opening it with the tpsDig program and clicking with the mouse pointer on each landmark in a specific order (one to six). Subsequent use of the other tps-programs (such as tpsSplin and tpsRelw) allows for superimposition of the landmarks and enables visual representation of the landmarks in relation to each other.

4.2.3.2 tpsRelw

Specimens were compared by means of consensus distribution and relative warps analysis.

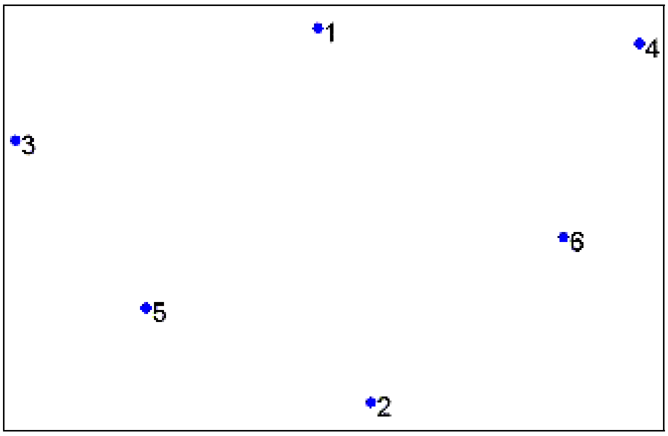


Figure 15. *Consensus shape generated from dataset with tpsRelw*

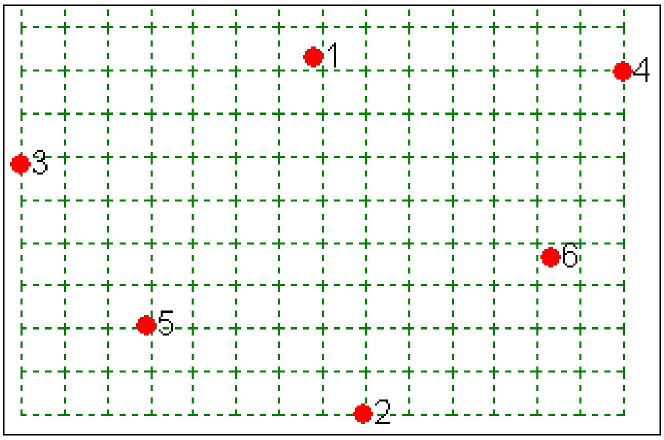


Figure 16. *Relative warp visualisation plot generated from dataset with tpsRelw*

4.2.3.3 tpsSplin

The reference shape of the spinal canal was determined with the program and the deviation from the average was visualised by means of thin-plate spline.

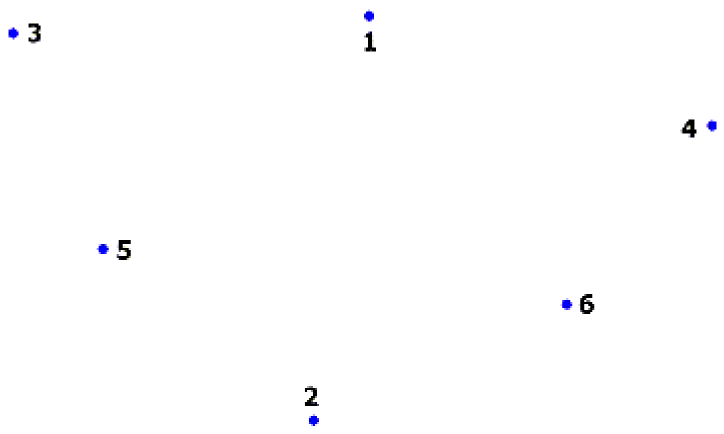


Figure 17. *Reference shape generated from dataset by tpsSplin*

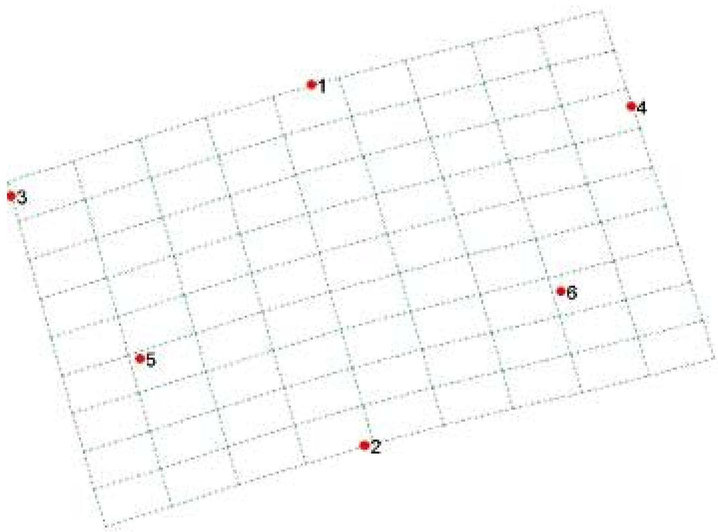


Figure 18. *Thin plate spline generated from dataset by tpsSplin. The thin plate spline indicates the deviation of the current dataset in relation to the reference shape*

4.2.3.4 IMP

4.2.3.4.1 TwoGroup6H

Statistical comparisons were done to determine if statistically significant differences occur between males and females.

5. RESULTS

5.1 Initial Skeletal Study

A skeletal study was conducted on skeletal material of 179 complete cervical vertebral columns (C3-C7) of the South African black population from the Pretoria Bone Collection at the University of Pretoria as well as the Raymond A. Dart Collection at the University of the Witwatersrand, to determine the dimensions of the cervical spinal canal.

The population was divided into males and females (90 and 89 per group respectively). These were subdivided into age categories (30-45; 46-60 and 61-75 years) to yield six subpopulations, five with 30 individuals and one with 29 individuals.

Age Group	Males	Females
30-45	30	30
46-60	30	30
61-75	30	29
Total	**90**	**89**

Table 6. *Number of individuals in each age category for skeletal study*

A Vernier digital calliper with an accuracy of 0.01 mm accuracy was used to take measurements on the skeletal material.

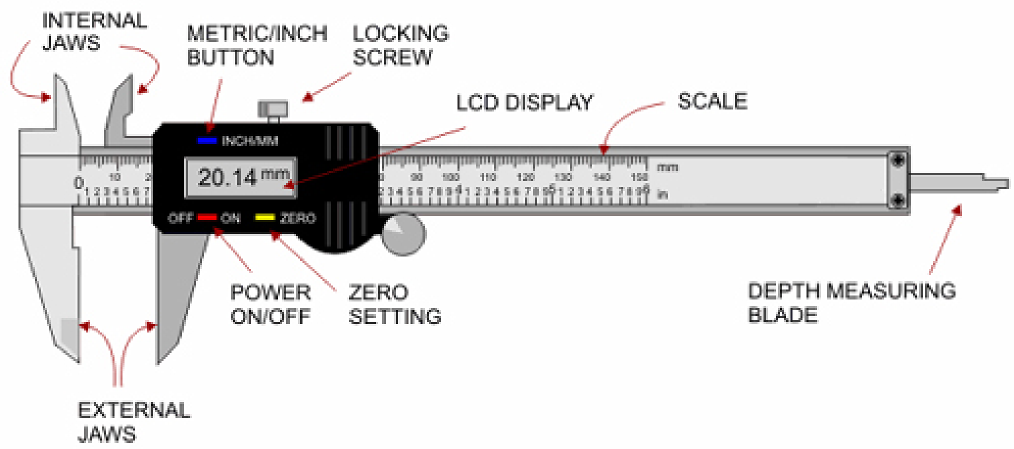


Figure 19. *An artist's representation of a Vernier digital calliper, indicating all calliper functionalities*[157].

The internal jaws of the calliper were used to measure the sagittal and transverse dimensions of the spinal. This was done by placing one jaw at the start point (e.g. midpoint of the posterior surface of the vertebral body) and sliding the calliper carefully until it reached the opposite point of the measurement (e.g. junction of the laminae), and recording the reading displayed on the LCD screen of the calliper (distance in mm).

The sagittal diameter of the vertebral body was measured by placing the external jaws over the vertebral body. The one jaw was placed on the anterior midpoint of the vertebral body and then the calliper was closed carefully until the other jaw reached the midpoint of the posterior surface of the vertebral body and recording the subsequent reading on the calliper.

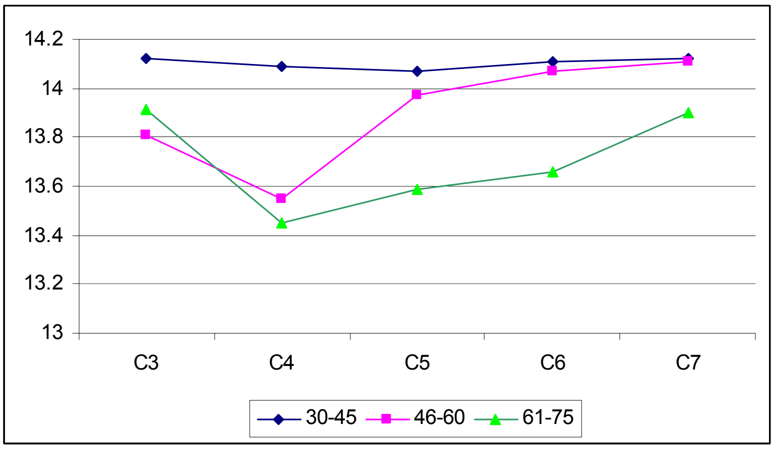
5.1.1 <u>Dimensions of the cervical spinal canal</u>

5.1.1.1 Influence of age on dimensions of the cervical spinal canal

With the sagittal diameter of the cervical spinal canal being the measurement of importance in this study the observed dimensions follow:

Vertebra	**30-45**		**46-60**		**61-75**	
	Mean (mm)	**Standard Deviation**	**Mean (mm)**	**Standard Deviation**	**Mean (mm)**	**Standard Deviation**
C3	14.12	1.16	13.81	1.38	13.91	1.35
C4	14.09	1.53	13.55	1.35	13.45	1.36
C5	14.07	1.37	13.97	1.16	13.59	1.36
C6	14.11	1.28	14.07	1.32	13.66	1.40
C7	14.12	1.31	14.11	1.29	13.90	1.34
Overall	**14.10**	**1.33**	**13.90**	**1.30**	**13.70**	**1.36**

Table 7. *Sagittal cervical spinal canal diameter indicating age differentiation in the skeletal study population*



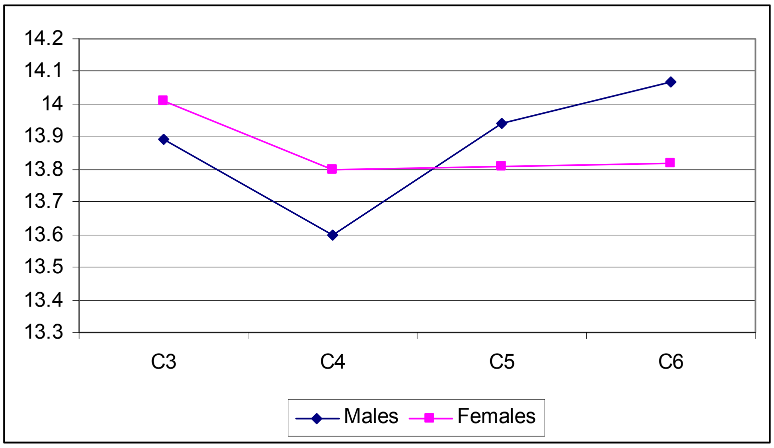
Graph 1. *Sagittal cervical spinal canal diameter indicating age differentiation in the skeletal study population*

In this study we can therefore agree with Sasaki, Kadoya and Iizuka[27] that the sagittal dimensions of the spinal canal decrease with age. C4 shows a statistically significant difference (P=0.03) between age groups 30-45 and 61-75 years and C4 is also significantly smaller than C3 also within these age categories.

5.1.1.2 Influence of sex on dimensions of the cervical spinal canal

Vertebra	**Males**		**Females**	
	Mean (mm)	**Standard Deviation**	**Mean (mm)**	**Standard Deviation**
C3	13.89	1.36	14.01	1.24
C4	13.60	1.48	13.80	1.39
C5	13.94	1.27	13.81	1.36
C6	14.07	1.40	13.82	1.28
C7	14.32	1.39	13.77	1.18
Overall	**13.96**	**1.37**	**13.84**	**1.29**

Table 8. *Sagittal cervical spinal canal diameter indicating sex differentiation in the skeletal study population*



Graph 2. *Sagittal cervical spinal canal diameter indicating sex differentiation in skeletal study population*

It is then also at the level of C3-C4 that a significant difference between males and females (P=0.04) start to appear which is also apparent at the level of C5-C6 (P=0.003) where the differentiation is highly significant. Also, the overall decrease in canal size between C3 and C7 shows a highly significant difference between males and females (P=0.0002) with the latter having a smaller canal of 13.85 mm (standard error [SE]=0.15) compared to the 13.96 (SE=0.2).

This study also concurs with that of Sasaki, Kadoya and Iizuka[27] that the canal of C4 has the smallest sagittal diameter (13.6 mm SE=0.15 in males and 13.8 mm SE=0.15 in females) but a significant difference exists between C4 and C5 in terms of both sex and age.

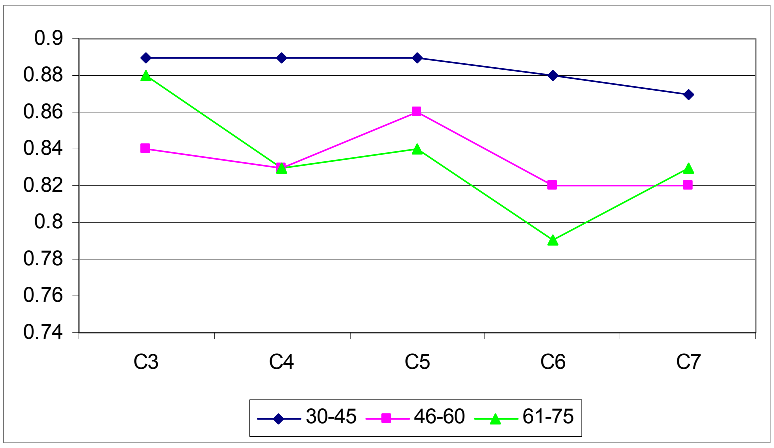
5.1.2 Pavlov's ratio

5.1.2.1 Influence of age on the Pavlov ratio

The calculation of the Pavlov ratio yielded interesting results:

Vertebra	**30-45**		**46-60**		**61-75**	
	Pavlov Ratio	**Standard Deviation**	**Pavlov Ratio**	**Standard Deviation**	**Pavlov Ratio**	**Standard Deviation**
C3	0.89	0.13	0.84	0.15	0.88	0.14
C4	0.89	0.15	0.83	0.15	0.83	0.16
C5	0.89	0.16	0.86	0.16	0.84	0.19
C6	0.88	0.14	0.82	0.16	0.79	0.19
C7	0.87	0.13	0.82	0.13	0.83	0.17
Overall	**0.88**	**0.14**	**0.83**	**0.15**	**0.83**	**0.17**

Table 9. *Pavlov's ratio for cervical spinal canal indicating age differentiation in the skeletal study population*



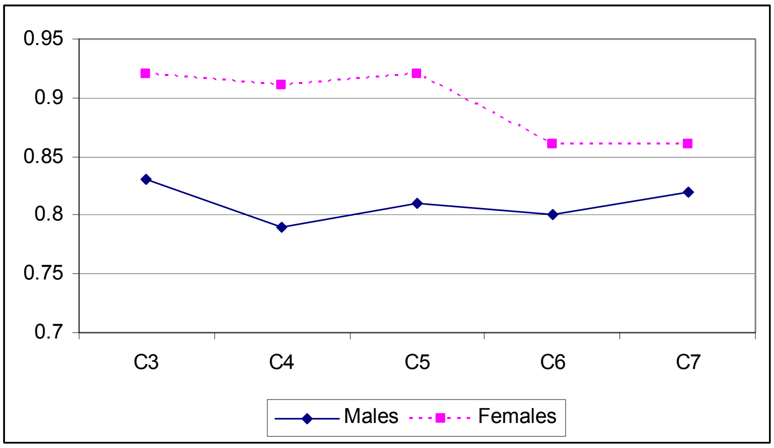
Graph 3. *Pavlov's ratio for cervical spinal canal indicating age differentiation in the skeletal study population*

According to the classification system as described by Pavlov *et al.,*[20]*.* it is evident that in this study population almost all cervical vertebrae from C3-C7 in the age categories 46-60 and 61-75 are stenotic (ratio below 0.85) with C6 in the last age category identifying itself to be a significant risk factor for lateral neurological injury and to be congenitally narrow (ratio below 0.8).

5.1.2.2 Influence of sex on the Pavlov ratio

Vertebra	Males		Females	
	Pavlov Ratio	Standard Deviation	Pavlov Ratio	Standard Deviation
C3	0.83	0.13	0.92	0.14
C4	0.79	0.14	0.91	0.15
C5	0.81	0.14	0.92	0.18
C6	0.80	0.15	0.86	0.19
C7	0.82	0.14	0.86	0.15
Overall	**0.81**	**0.14**	**0.89**	**0.16**

Table 10. *Pavlov's ratio for cervical spinal canal indicating sex differentiation in the skeletal study population*



Graph 4. *Pavlov's ratio for cervical spinal canal indicating sex differentiation in the skeletal study population*

Findings from the skeletal study also indicate that the Pavlov ratio is much higher in females (0.89 SE=0.02) than in males (0.81 SE=0.02) where the ratio renders all cervical vertebrae in males stenotic.

5.1.3 Intra-observer variation

All measurements were taken twice by the same person to minimise intra-observer variation. The mean of the two measurements were used to reflect measurements and the intra-observer variation was determined by means of calculating the intra-class correlation coefficient (Rho) for the measurements. A Rho value of 1 indicates that there was no variation between the two measurements. The results follow:

Vertebra	**Rho – Vertebral body anteroposterior**	**Rho – Spinal canal anteroposterior**
C3	0.97	0.96
C4	0.99	0.99
C5	0.93	0.97
C6	0.99	0.99
C7	0.99	0.99
Overall	**0.97**	**0.98**

Table 11. *Rho-values reflecting intra-observer variation for measurements taken on skeletal material*

5.1.4 Inter-observer variation

The same measurements were taken by an independent observer on a random sample of the same skeletal material to determine inter-observer variation. The random sample consisted of 28 complete vertebral columns (C3-C7) extracted from the same study population, and was distributed evenly across the same age and sex categories as for the skeletal study. The observer's measurements were compared with the original measurements and the intra-class correlation coefficient (Rho) was calculated.

Vertebra	**Rho – Vertebral body anteroposterior**	**Rho – Spinal canal anteroposterior**
C3	0.97	0.97
C4	0.98	0.98
C5	0.98	0.98
C6	0.97	0.95
C7	0.95	0.98
Overall	**0.97**	**0.97**

Table 12. *Rho-values reflecting inter-observer variation for measurements taken on skeletal material*

With the Rho-values for the inter-observer variation being very close to 1, this indicates that the study would be easily duplicable and would yield very similar results.

5.2 CT-scans

5.2.1 Comparison of measurements on skeletal material and CT-scans

Results from the CT-scan measurements yielded very similar results to those obtained from measurements on the material for the skeletal study.

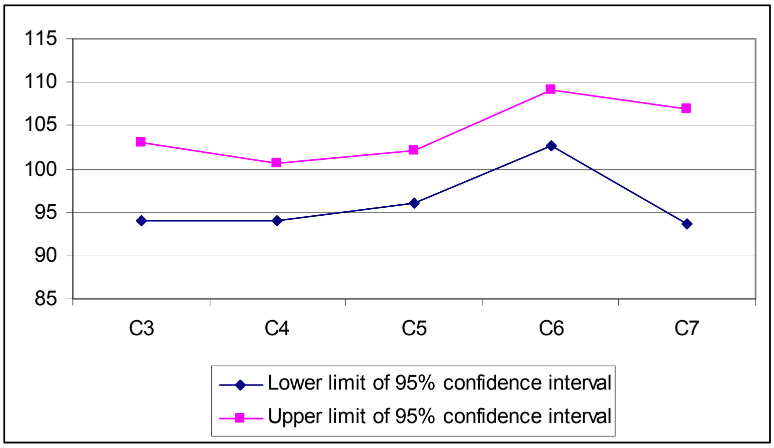
Vertebra	**Males**		**Females**	
	Skeletal material (mm)	**CT-scans (mm)**	**Skeletal material (mm)**	**CT-scans (mm)**
C3	13.89	13.13	14.01	13.47
C4	13.60	13.09	13.80	13.51
C5	13.94	13.33	13.81	13.59
C6	14.07	14.49	13.82	14.24
C7	14.32	14.14	13.77	13.53
Overall	**13.96**	**13.64**	**13.84**	**13.67**

Table 13. *Comparison of cervical spinal canal dimensions measured on skeletal material and CT-scans*

Measurements of the anteroposterior dimension of the cervical spinal canal taken on skeletal material highly correspond with measurements taken on CT-scans. This is evident from the values of the 95% confidence intervals observed when comparing the CT-scan measurements with those taken on skeletal material.

Vertebra	Lower limit of 95% confidence interval	Upper limit of 95% confidence interval	Value of Interval (Upper - Lower)
C3	94	103.1	9.1
C4	94	100.7	6.7
C5	96	102.1	6.1
C6	102.7	109.2	6.5
C7	93.6	106.9	13.3
Overall	**96.06**	**104.4**	**8.34**

Table 14. *95% Confidence interval values for comparison of measurements on CT-scans relative to measurements of skeletal material.*



Graph 5. *95% Confidence interval values for comparison of measurements on CT-scans relative to measurements of skeletal material.*

From the 95% confidence interval it can be said that, relative to the dimensions measured on the skeletal material, the accuracy of the dimensions measured on the CT-scans can be as low as 96% and as high as 104,4%, on average.

This study therefore concludes that no significant difference can be observed when comparing dimensions observed on skeletal material and CT-scans.

5.2.2 Intra-observer variation

Measurements of the dimensions of the cervical spinal canal were taken twice by the same person in order to minimise intra-observer variation. The two measurements were used to determine the intra-observer variation by means of calculating the intra-class correlation coefficient (Rho) for the measurements.

Vertebra	**Rho – Vertebral body anteroposterior**	**Rho – Spinal canal anteroposterior**
C3	0.98	0.97
C4	0.98	0.98
C5	0.98	0.98
C6	0.98	0.99
C7	0.98	0.98
Overall	**0.98**	**0.98**

Table 15. *Rho-values reflecting intra-observer variation for measurements taken on CT-scans*

The Rho-values are very close to 1, indicating high repeatability of measurements and results.

5.3 Occurrence of vertebral osteophytes within the cervical spinal canal

The occurrence of vertebral osteophytes within the vertebral canal (on the posterior aspect of the vertebral body or on the laminae, projecting into the spinal canal - directly influencing the size and shape of the canal) was determined by studying both the superior and inferior surface of the vertebral body.

The occurrence of osteophytes was classified according to the following grading scale:

- Grade 0 : No osteophytes present
- Grade 1 : Very slight ossification of soft tissue present, almost no protrusion into the spinal canal
- Grade 2 : Ossification clearly present and osteophyte(s) protrude into the spinal canal, the osteophytes slightly changing the shape of the spinal canal
- Grade 3: Very large osteophytes protruding into the spinal canal, dramatically altering the shape of the spinal canal

For the purposes of meaningful statistical analysis, the grades were merged into:

- Grade 0 : No osteophytes present or very slight osteophytes not protruding into the canal (Previous grades 0 + 1)
- Grade 1 : Osteophytes clearly present with protrusion into the spinal canal (Previous grades 2 + 3; there were only 2 instances of grade 3 osteophytes out of a population of 535 vertebrae)

Figure 20. *Cervical vertebra with Grade 0 osteophyte classification.*

Figure 21. *Cervical vertebra with Grade 1 osteophyte classification.*

No osteophytes occurred on the laminae of the spinal canal. If osteophytes were present, they occurred only on the vertebral body. For the purpose of this study, only osteophytes occurring in or protruding into the cervical spinal canal were noted. Of the 535 vertebrae (107 vertebral columns, C3 to C7) that were examined, 78% had osteophytes. Only 117 vertebrae had no osteophytes.

The occurrence of vertebral osteophytes were compared on various criteria, to determine if differences exist between the different age groups and between the sexes, and it was also noted whether the osteophytes occurred on the superior or inferior aspects of the vertebral body. The results follow:

5.3.1 Influence of age on occurrence of vertebral osteophytes

5.3.1.1 Superior surface of vertebrae

The following vertebrae showed statistical significance in terms of osteophyte occurrence on the superior surface of the vertebral body related to age differences

- C6 ($p<0.001$ - Fisher's exact test)
- C7 ($p=0.006$ - Fisher's exact test)

For both vertebrae the difference occurs between age group 46-60 and 61-75 with the latter having a higher incidence of osteophyte occurrence.

5.3.1.2 Inferior surface of vertebrae

The following vertebrae showed statistical significance in terms of osteophyte occurrence on the inferior surface of the vertebral body relating to age differences

- C6 ($p=0.001$ - Fisher's exact test)
- C7 ($p<0.05$ - Fisher's exact test)

For both vertebrae the difference occurs between age group 46-60 and 61-75 with the latter having a higher incidence of osteophyte occurrence.

It can be concluded that C6 and C7 are the most affected by vertebral osteophytes protruding into the spinal canal, where these osteophytes occur with advancing age.

In this study population persons over the age of 60 have a significantly higher incidence of vertebral osteophytes protruding into the cervical spinal canal than their younger counterparts.

5.3.2 Influence of sex on occurrence of vertebral osteophytes

No statistical difference occurred at any level between males and females in terms of the occurrence of vertebral osteophytes within the cervical spinal canal.

5.3.3 Occurrence of vertebral osteophytes on superior / inferior aspects of spinal canal

Making use of McNemar's test for symmetry it was determined that, within this study population, osteophytes occur more frequently on the superior aspect of the cervical spinal canal at the levels of C3 and C7, whilst the inferior aspect of the vertebral body has higher occurrence levels of osteophytes at the levels of C4, C5 and C6.

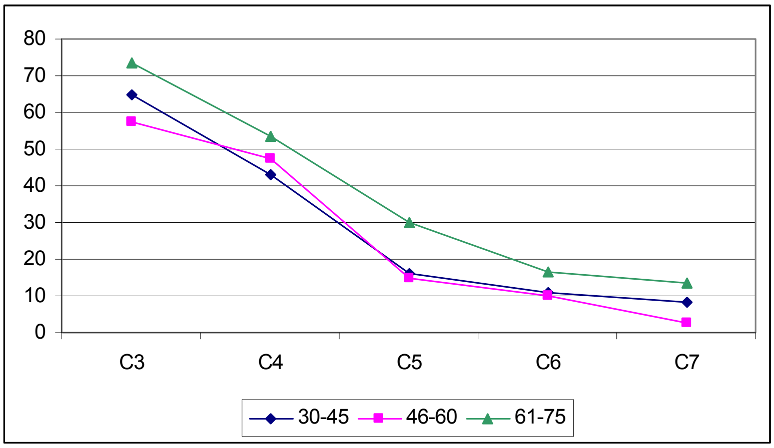
5.4 Occurrence of ossification of the posterior longitudinal ligament (OPLL)

This study found that there is no statistical evidence showing that there are any differences between the occurrence of OPLL in males and females or between the different age categories. However, OPLL does occur.

5.4.1 Incidence of OPLL amongst age groups

Age Group	**C3 (% occurred)**	**C4 (% occurred)**	**C5 (% occurred)**	**C6 (% occurred)**	**C7 (% occurred)**
30-45	64.8	43.2	16.22	10.8	8.1
46-60	57.5	47.5	15	10	2.5
61-75	73.3	53.3	30	16.7	13.3
Total	**64.5**	**47.7**	**21**	**12.2**	**7.5**

Table 16. *Percentage incidence of ossification of the posterior longitudinal ligament in different age groups*



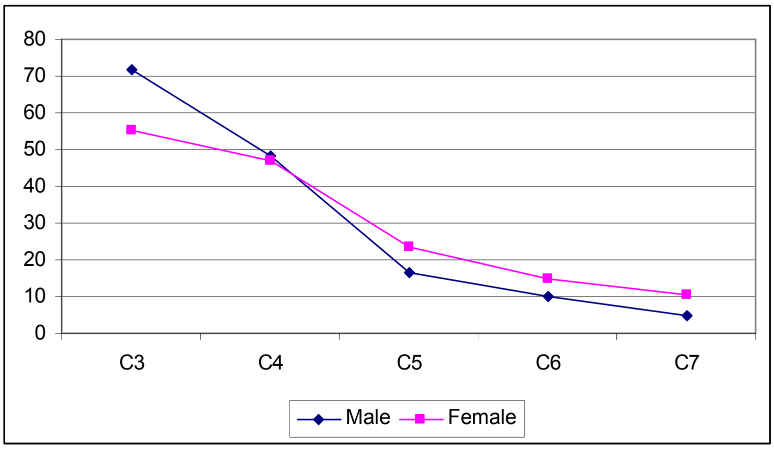
Graph 6. *Percentage incidence of ossification of the posterior longitudinal ligament in different age groups*

It is evident from the above table that OPLL occurs mostly at the level of C3 with a frequency of 64.5% after which the frequency decreases consistently down the cervical spine to C7 where the occurrence of OPLL is a mere 7.5%.

5.4.2 Incidence of OPLL amongst sex groups

Sex	**C3 (% occurred)**	**C4 (% occurred)**	**C5 (% occurred)**	**C6 (% occurred)**	**C7 (% occurred)**
Male	71.7	48.3	16.7	10	5
Female	55.3	46.8	23.4	14.9	10.6
Total	**64.5**	**47.7**	**19.6**	**12.2**	**7.5**

Table 17. *Percentage incidence of ossification of the posterior longitudinal ligament in different sex groups*



Graph 7. *Percentage incidence of ossification of the posterior longitudinal ligament in different sex groups*

The frequency of incidence of OPLL follows a similar pattern for both males and females as for the age groups, with a high occurrence of OPLL at C3, showing a steady decline from C4 to C6 and a much lower occurrence at C7.

5.5 Geometric Morphometry

It is widely accepted that the cervical spinal canal is large and triangular in shape. Although this is true, due to the nature of the contents of the spinal canal and its dimensions, even slight deviations in shape may cause spinal cord impingement due to spinal stenosis.

It is important to define consensus spinal canal shapes for males and females, derived from a large and meaningful sample size, and to discuss observed aberrations thereof in order to determine sex predisposal to stenosis. It is also essential to establish the age of onset of spinal canal shape changes in order to take preventative care.

5.5.1 Influence of age on shape of cervical spinal canal

5.5.1.1 Relative warp analysis

Relative warp analysis allows the visualisation of deformations of the consensus configuration corresponding to a point in the space spanned by a particular pair of relative warps. The actual space of the shapes can be observed. A grid with no deformation indicates that the shape mimics the consensus shape. Bending of the grid is indicative of deformation, and the point at which deformation occurs is the landmark that has “shifted” relative to the consensus shape.

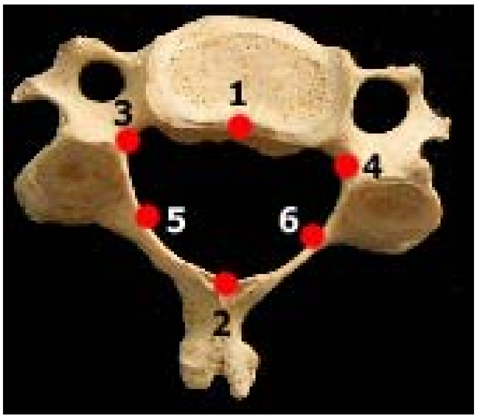


Figure 22. *Digital photograph indicating landmarks 1 to 6*

Landmark allocation on cervical spinal canal.

1. Midpoint of the posterior surface of vertebral body
2. Junction of laminae of spinal canal
3. Junction of left lamina and pedicle
4. Junction of right lamina and pedicle
5. Midpoint on lamina between point 2 and 3
6. Midpoint between point 2 and 4

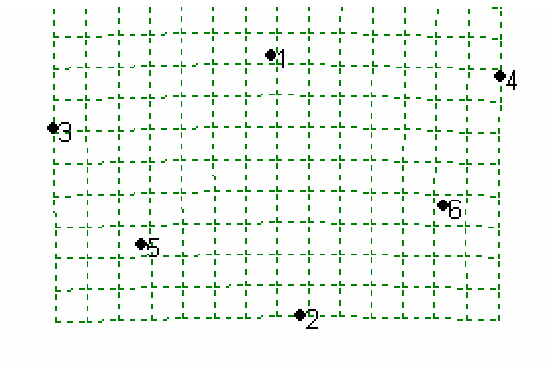


Figure 23. *Thin plate spline for age group 30-45 years*

Age group 30-45years

Relative to the consensus shape, in the youngest age group landmark 1 is situated further away from landmark 2. This indicates that the spinal canal sagittal diameter is larger in individuals 30-45 years, than in the consensus shape.

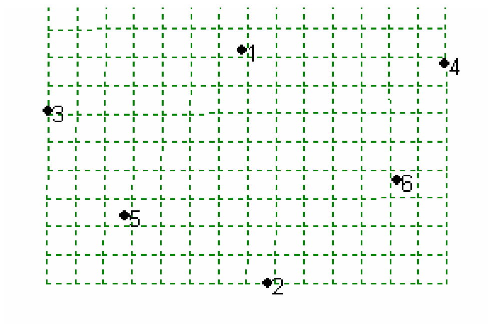


Figure 24. *Thin plate spline for age group 46-60 years*

Age group 46-60 years

Almost no bending of the grid is observed, indicating that this age group's shape is closest to that of the consensus shape. Landmark 1 is closer to landmark 2 than observed in the younger age category (30-45), indicating a smaller sagittal diameter of the cervical spinal canal.

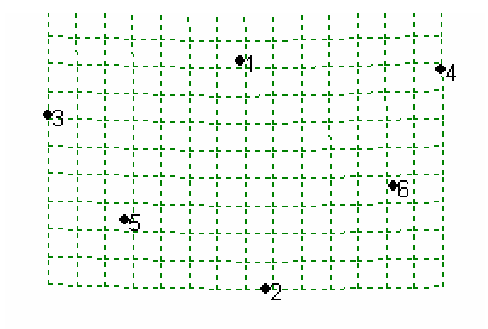


Figure 25. *Thin plate spline for age group 61-75 years*

Age group 61-75 years

Relative to the consensus, landmark 1 is closer to landmark 2 indicating a decreased sagittal canal diameter. It is in this age category that the sagittal diameter is the smallest.

Observations from the relative warps analysis correspond well with results obtained from physical measurements on both skeletal material and CT-scans, also indicating decreased sagittal spinal canal dimensions.

5.5.2 Influence of sex on shape of cervical spinal canal

5.5.2.1 Relative warp analysis

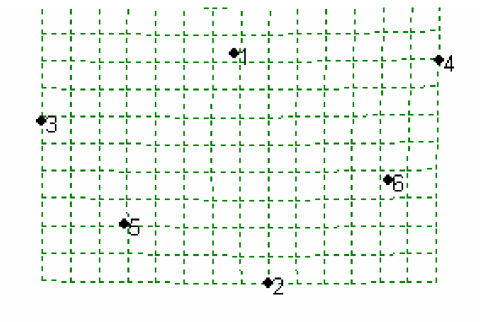


Figure 26. *Thin plate spline for males*

Males

Almost no bending of the grid is observed, indicating that the shape of the cervical spinal canal in males is closest to that of the consensus shape. Landmark 1 is closer to landmark 2 than observed in females.

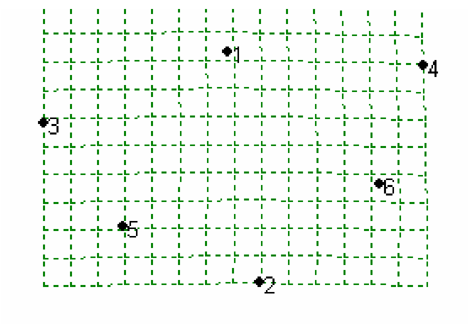


Figure 27. *Thin plate spline for females*

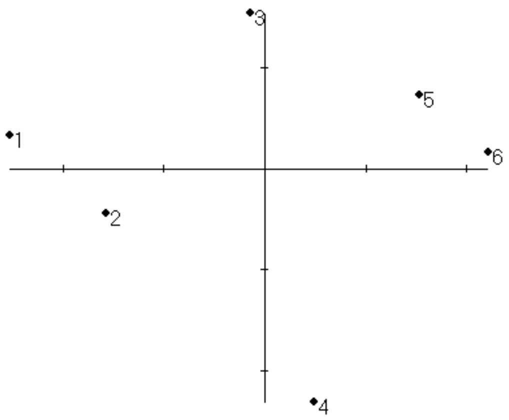
Females

Relative to the consensus shape, landmark 1 is situated further away from landmark 2 in females. This clearly indicates that the spinal canal sagittal diameter is larger in females than in males. The bending of the grid indicates deviation from the consensus shape (average/mean shape).

The shape of the cervical spinal canal differs highly significantly between males and females:

- Age group 30-45: $p<0.001$
- Age group 46-60: $p<0.001$
- Age group 61-75: $p<0.001$
- Overall difference between males and females: $p<0.001$

This is clearly illustrated in the following relative warp analysis distribution graph:



Categories

1. Females age 30-45
2. Females age 46-60
3. Females age 61-75
4. Males age 30-45
5. Males age 46-60
6. Males age 61-75

Figure 28. *Relative warp ordination plot comparing males and females from all age categories*

All females (points 1, 2 and 3) are situated to the left of the Y-axis in this graph whereas all males (points 5, 6 and 7) are all located to the right of the Y-axis of the graph.

The landmarks most affected by this difference is landmarks 1 and 2 (posterior aspect of the vertebral body and the junction of the laminae of the spinal canal). It is these landmarks that define the sagittal diameter of the cervical spinal canal and it can therefore be concluded that it is this dimension that affects the shape of the cervical spinal canal the most.

5.5.2.2 Thin-plate spline

Thin-plate spline is a function that maps all points in the physical space of the reference onto corresponding points in the space of the individual specimen, based on the physical properties of a thin sheet of metal. It models the form taken by a metal plate that is constrained at some combination of points and lines, and is otherwise free to adopt the form that minimises bending energy.

5.5.2.2.1 Male age category differences

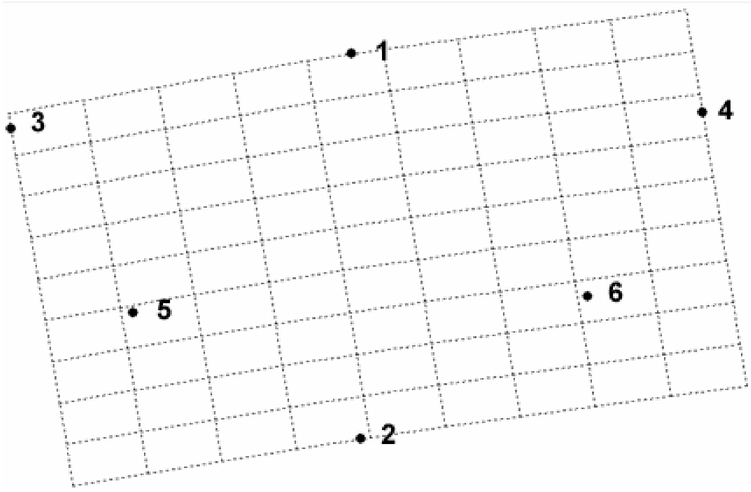


Figure 29. *Thin plate spline for males 30-45*

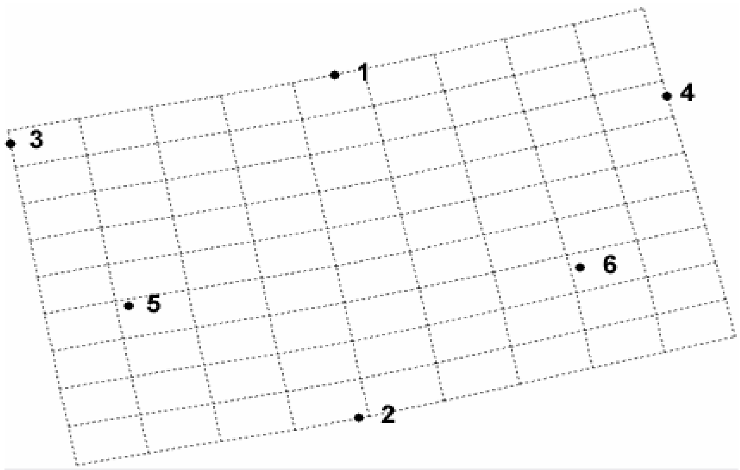


Figure 30. *Thin plate spline for males 46-60*

In males, differences between age groups become evident in individuals older than 45 years. In the above thin-plate splines it is clear that whereas landmark 1 is far from landmark 2 in the first image (males 30-45), it is much closer to landmark 2 in the second image (males 46-60). It can be inferred that, in males, age will start playing a role in the changing dimensions of the cervical spinal canal after age 45, as it is only after this age that shape differences start to appear. Thin-plate splines for males 46-60 and males 61-75 appear very similar.

Goodall's F-test showed that there is very highly significant difference (p<0.001) between all age categories, with the greatest difference between males aged 30-45 and 46-40 years of age. This confirms what is observed on the thin-plate splines.

Although there is also a very highly significant difference between age groups 46-60 and 61-75 (p<0.001 *Goodall's F-test*), indicating that continuous shape change occur from age 46 years and onward, the change is of a lower magnitude when compared to the change observed between the youngest two age categories.

5.5.2.2.2 Female age category differences

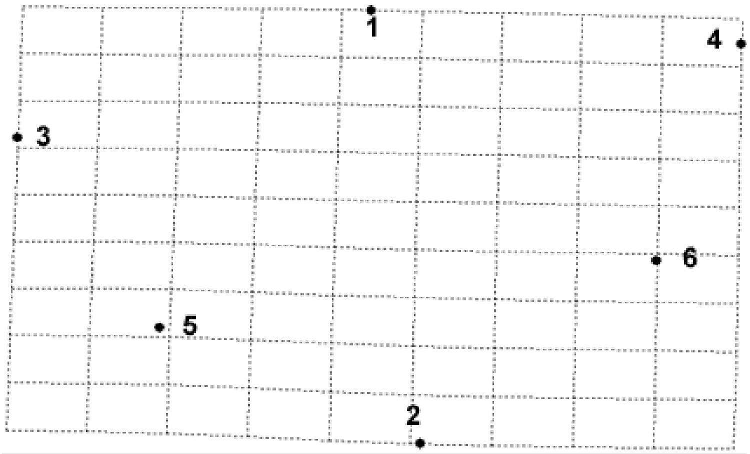


Figure 31. *Thin plate spline for females 46-60*

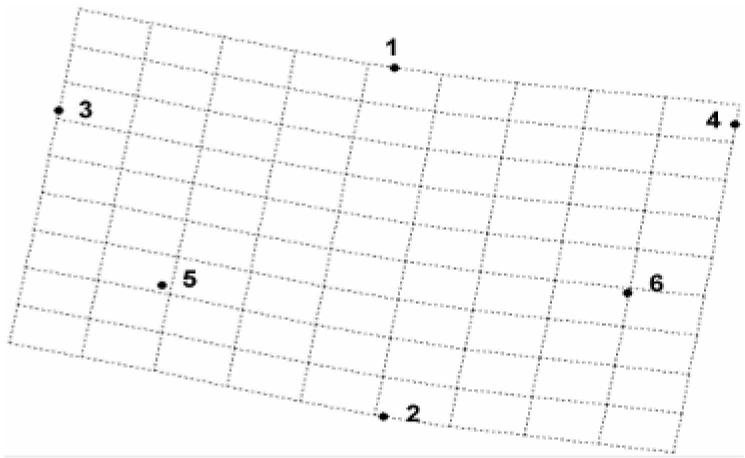


Figure 32. *Thin plate spline for females 61-75*

In contrast to males, the differences between the age groups in females only become evident in the oldest age group (age 61-75), where landmark 1 is closer to landmark 2 than in the younger age category (age 46-60).

It can therefore be stated that, in females, age will only start playing a role in the changing dimensions of the cervical spinal canal after age 60, as it is only after this age that shape differences start to appear. The thin plate splines for females 30-45 and 46-60 are very similar.

Although Goodall's F-test detects a slightly significant difference between females aged 30-45 and 46-60 (p=0.01), it detects a very highly significantly difference (p<0.001) between age groups 46-60 and 61-75.

This confirms observations from the thin-plate splines, indicating that the shape change is delayed in females when compared to males and manifests only above the age of 60 years.

6. DISCUSSION

The main objective of this study was to determine, within a large and reliable sample size, the dimensions of the cervical spinal canal in the South African Negroid population. With this information, the study hopes to empower physicians and surgeons alike, to make informed decisions regarding diagnosis and treatment of cervical spinal stenosis within this population group.

Not only were clear dimensions established and found to be different from other study populations, but for the first time the shape of the cervical spinal canal has been morphometrically described and comparisons drawn between males and females. A correlation has now been established between the sex related differences in the shape of the canal and possible symptomatic outfall.

6.1 Cervical spinal canal differences observed between males and females

6.1.1 Dimensions of the cervical spinal canal

This study confirmed results observed in other study populations in terms of differences observed between males and females. The cervical spinal canal of males is larger in males than observed in their female counterparts, and this observation is perpetuated into all age groups.

6.1.2 Shape of the cervical spinal canal

Size differences should however, be discussed in light of the shape of the cervical spinal canal in both sexes. Although the relative warp analyses reveal that the consensus shapes of males and females appear similar in that the basic shape is triangular as described in textbooks, there are statistically significant differences between the sexes throughout all the age groups. The female canal has a more rounded shape whereas the male canal is more triangular.

Figure 33. *Triangular shaped cervical spinal canal of males*

Figure 34. *Female cervical spinal canal with more rounded shape*

Considering this, it is important to note that any change in the dimensions of the cervical spinal canal in the anteroposterior direction due to various pathological conditions that include, but is not limited to osteophytosis and ossification of the posterior longitudinal ligament (OPLL) on the posterior aspect of the vertebral body, will result in the triangular male canal assuming a trefoil like shape, possibly impinging the spinal cord, whereas in females, manifesting with the same degree of pathology in the same dimension, the rounder canal will assume a still "safe" triangular shape.

Figure 35. *Triangular shaped cervical spinal canal of males assumes trefoil-like shape when pathology (e.g. osteophytes) is present*

Figure 36. *Female cervical spinal canal with more rounded shape assumes a still "safe" triangular shape when pathology is present*

As there are no statistical differences between males and females in terms of the occurrence and distribution pattern of both osteophytes occurring in or protruding into the spinal canal and ossification of the posterior longitudinal ligament, the conclusion can be drawn that, although the female canal is narrower, it will not lend itself to myelopathy and impingement of the spinal cord to such an extent as the male canal potentially could.

6.1.3 Pavlov's ratio

Due to the nature of the measurements used to calculate the ratio (mid-sagittal diameter of the spinal canal divided by the mid-sagittal diameter of the corresponding vertebral body) the difference in shape of the cervical spinal canal between the sexes may also contribute to accounting for the differences observed in the Pavlov ratio.

Because the vertebral body naturally protrudes further into the spinal canal in males than in females causing the male canal to assume a triangular shape (rather than the rounder shape of the canal in females) the ratio will be affected markedly in males with even the slightest manifestation of pathology. This could possibly explain why the ratio defines all males within this study population as having stenotic spinal canals with the ratio at all levels below 0.85, whilst the females are all classified as normal with a ratio above 0.85.

At this stage it is fitting to explore the differences between males and females in terms of the age of onset of spinal canal shape changes. In males, canal shape changes can be observed much earlier (after age 45) than in females where the changes only start after age 60. As discussed earlier, these shape changes will alter the Pavlov ratio and will explain the discrepancy between the ratios for the two sexes.

6.2 Cervical spinal canal differences observed between age groups

6.2.1 Dimensions of the cervical spinal canal

The mid-sagittal diameter of the cervical spinal canal decreases with age with C4 being the level affected most by ageing. The dimensions of C3 and C4 change dramatically after age 45 whereas changes in C5 to C7 only appear after age 60.

It is interesting to note that the grouping of these changes correspond well with the occurrence of osteophytosis and OPLL within this study population. C3 and C4 have the highest occurrence of ossification of the posterior longitudinal ligament (OPLL) whereas C6 and C7 are the only vertebrae that have a significantly higher incidence of osteophytes occurring in- or protruding into the spinal canal with increased age, especially after age 60.

6.2.2 Shape of the cervical spinal canal

Geometric morphometry indicate that the shape of the cervical spinal canal significantly changes with age throughout all age groups and across both sexes. By studying the occurrence and incidence of osteophytosis and OPLL we can now account for possible changes in the shape of the canal.

While shape changes in C3 and C4 may be largely due to the occurrence of OPLL (as no statistically significant occurrence of osteophytes occur at this level with increased age), changes in C6 and C7 can potentially be attributed to the occurrence of osteophytes on the posterior aspect of the vertebral body (incidence of OPLL on these levels are far lower than for C3 and C4).

It is important however, to note that although some shape change occurs after 45, the majority of change in the canal shape is delayed in females until after age 60. In their male counterparts, on the other hand, prominent shape changes become evident after the age of 45.

6.3 Correlation of measurements on skeletal material and CT-scans

This study finds that no statistically significant differences can be observed between measurements taken on skeletal material and CT-scans. This is confirmed by very high 95% confidence intervals (values between 96 and 104) in spite of the fact that measurements on CT-scans occasionally proved to be difficult due to lack of clear definition of borders on the CT-scans, or due to poor quality of the images.

By measuring all dimensions twice, any discrepancies seem to dissipate and the high Rho values obtained from calculating the intra-observer variation clearly indicate repeatability of the measurements, both on CT-scans and skeletal material.

This study can also infer from these results that the CT-scan angle differences due to the curvatures of the cervical spine do not seem to have a significant effect on the measured dimensions.

If facilities are available for CT-scans and if it is financially possible, CT-scanning offers an ideal method for detecting cervical spinal stenosis.

6.4 Application of the universal standards on this study population

6.4.1 Normal dimensions of the cervical spinal canal in terms of other populations

This study has shown that the sagittal diameter of the cervical spinal canal in the South African black population is consistently smaller than that of the Japanese population as was described by Sasaki, Kadoya and Iizuka[27]. This occurs across all the vertebrae (C3 to C7) by a value of more than 1.5mm and even when considering the standard deviation of their study the South African black population is still below or at their lower limit. The cervical region of the South African black population proved to have similar dimensions to the Korean population studied by Lee *et al.,* [3].

Correlation with studies on other population groups has enabled this study to prove it's universality in terms of general trends and to conclude that – although trends (such as differences between males and females, vertebral level of most dimensional deviation and increased spinal canal changes with age) can be observed in all population groups – the magnitude and extent of these differences vary significantly between groups and it is therefore important to have clear and definite guidelines for each population group.

The reliability of universal indicators for the diagnosis of cervical spinal stenosis were compared, discussed and found to be inaccurate in terms of application on the South African Black population. This study has shown that both ethnicity and sex have to be considered when diagnosing cervical spinal stenosis within this population group, hence the need for clear and reliable dimensional guidelines and indicators.

6.4.2 Comparison of this study with the studies of Taitz[2,29] on the same population group

This author strongly disagrees with the findings of Taitz that there are no differences between the mid-sagittal diameters of the cervical spinal canal in males and females, and that the dimensions of the canal do not change with age.

This study has proven conclusively and with a large study population that there are statistically significant differences between cervical spinal canal dimensions of males and females and among the age groups. This has been confirmed by studying changing shapes of the cervical spinal canal between sexes and age groups and, with the aid of geometric morphometry, visualising these changing dimensions.

However, this study does confirm findings by Taitz that osteophytes occur more frequently in older individuals, and that no differences exist in the incidence of osteophytosis incidence between sexes. Results from this study adds to that of Taitz and also determined that C6 and C7 are the cervical vertebral levels most affected by osteophytosis and that incidence of osteophytes on these levels are only markedly and significantly elevated after the age of 60.

6.4.3 Pavlov's ratio

This study raises the question whether the Pavlov ratio[20] is at all reliable as a predictive measure of cervical spinal stenosis within the South African black population. The dimensions of the cervical spinal canal indicate that in no age category, or even when differentiating between males and females regardless of age, the canal can be considered stenotic or even remotely so as all means are well above the 12mm dividing point.

Although this study has attempted to explain why the ratio in this study population is so much smaller for males than females within this study population, and concluded that the shape of the canal is probably the largest contributing factor, it seems that the ratio tends to over estimate the occurrence of stenosis and can not be reliably applied to determine the presence or absence of cervical spinal stenosis.

6.4.4 Division point between stenotic and non-stenotic cervical spinal canals

The use of a set dimension, such as the universal 12mm dividing point between normal and stenotic canals could be considered more reliable than the Pavlov ratio.

Due to the relatively small dimensions of the cervical spinal canal in the South African black population (smaller than the dimensions of the Japanese population[27]), division points proposed by Torg[7] (14mm for C4-C6) and Higo[69] (14mm for males and 13mm for females) will also over-estimate the prevalence of cervical spinal stenosis within this population group as the average diameter for this population group is 13.9mm.

7. CONCLUSION

This study was limited by the absence of data to determine if individuals included in this study were ever diagnosed with cervical pathology, and if any associated symptoms were experienced. As such, no correlation could be drawn between dimensions of the canal and actual symptomatic cervical spinal stenosis.

It would be advantageous to pursue studies specifically investigating this correlation, and specifically within this population group, because the dimensions of the cervical spinal canal appear to differ to a large extent from other population groups. Universal indicators, such as the Pavlov ratio, also appear not to be applicable to this group.

Although this study is comprehensive in terms of sample size, and can be deemed reliable in terms of establishing the metric dimensions of the cervical spinal canal (midsagittal diameter of the canal), it has to be noted that the determination of cervical spinal canal shape by means of geometric morphometry has never been attempted before, and as such should be considered as an introductory study.

The results that were obtained by geometric morphometry in this study played an integral role in explaining the dimensional changes observed with ageing and the differences in males and females that relate to possible symptomatic outfall. It is precisely because geometric morphometry deals with spatial dimensions, rather than metric ones, that its result paves the way to explore inherent differences between the sexes, rather than developmental changes.

Previously described developmental changes, such as osteophytosis that occurs with ageing, was presumed to be the main reason for different metric dimensions observed between males in females. This study however has shown that there is no statistically significant difference between males and females in terms of osteophyte distribution or severity at any level – suggesting that differences observed are due to something other than osteophytic pathology. And this could very well be due to the inherent differences as described above.

Further morphometric studies of the cervical spinal canal is encouraged to determine if shape differences between males and females are also universal trends and if so, to obtain clear statistical data to correlate these differences with symptomatic cervical spinal stenosis.

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9. APPENDICES

9.1 Appendix A: List of Abbreviations

Abbreviation	Meaning
mm	millimetre
cm	centimetre
OPLL	Ossification of the posterior longitudinal ligament
MRI	Magnetic resonance imaging
CT	Computed tomography
KFA	Klippel-Feil anomaly
µg	microgram
x-ray	Plain radiograph
IMP	Integrated morphometrics package
mm^2	square millimetre
P	p-value
SE	Standard error
Rho	Correlation coefficient
C	Cervical vertebra
T	Thoracic vertebra
tps	Thin plate spline

9.2 Appendix B: List of Formulas

Formula name	Mathematical formula	Purpose of formula
Procrustus distance	$d_P = \sqrt{1 - \lvert \sum_{j=1}^{m} z_1^j \bar{z}_2^j \rvert^2}$	Procrustus distance provides a measure of coincidence of two point sets.
Standard Error	SE = $\delta^2 / \sqrt{n}$	The standard deviation of the difference between the measured or estimated values and the true values.
Standard Deviation	$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x})^2}$	The standard deviation of a sample is the measure of the spread of its values.
95% Confidence interval	Pr (L ≤ μA - μB ≤ U) = 0.95	Describes probability that the difference between means is at least L (Lower value) and at most U (Upper value) with 95% confidence.
Fisher's exact T-test	$P = \frac{(R_{R1}!R_{R2}!)(C_{R1}!C_{R2}!)}{N!\prod_{ij} a_{ij}!}$	T-test to accurately determine the p-value of a small sample.
Rho (Correlation coefficient)	$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$	Describes relationship between two variables without making any assumptions about the frequency distribution of the variables.

McNemar's test for symmetry	$\chi^2 = \frac{(\lvert b - c \rvert - 1)^2}{b + c}$	Non-parametric method used on nominal data to determine whether row and column marginal frequencies are equal.
Hotelling's t^2-test	$t^2 = n(\mathbf{x} - \mu)'\mathbf{W}^{-1}(\mathbf{x} - \mu)$	Generalization of Student's t statistic used in multivariate hypothesis testing
Mean	$\mu = \sum X / N$	Commonly called average, mean is the sum of all scores divided by the number of scores

9.3 Appendix C: Complete dataset

9.3.1 Dimensions of the cervical spinal canal – measurements on skeletal material and CT-scans

Dataset Key: Actual measurement values in mm

- ID – For purposes of keeping patient anonymity, corresponding numbers were assigned for each individual
- IdIn – Numbers assigned for keeping track of measurements taken by the two independent observers in order to determine inter-observer variation
- M – Different measurements taken
  - 1: First measurement of skeletal material by author
  - 2: Second measurement of skeletal material by author
  - 3: First measurement of skeletal material taken by independent observer
  - 4: Second measurement of skeletal material taken by independent observer
  - 5: First measurement of CT-scans by author
  - 6: Second measurement of CT-scan by author
- Age – Age category
  - 1: Age 30-45 years
  - 2: Age 46-60 years
  - 3: Age 61-75 years
- Sex – Sex of individual
  - 1: Male
  - 2: Female

- w11 – C3 Anteroposterior vertebral body
- w12 – C3 Sagittal diameter of spinal canal
- w13 – C3 Transverse diameter of spinal canal
- w21 – C4 Anteroposterior vertebral body
- w22 – C4 Sagittal diameter of spinal canal
- w23 – C4 Transverse diameter of spinal canal
- w31 – C5 Anteroposterior vertebral body
- w32 – C5 Sagittal diameter of spinal canal
- w33 – C5 Transverse diameter of spinal canal
- w41 – C6 Anteroposterior vertebral body
- w42 – C6 Sagittal diameter of spinal canal
- w43 – C6 Transverse diameter of spinal canal
- w51 – C7 Anteroposterior vertebral body
- w52 – C7 Sagittal diameter of spinal canal
- w53 – C7 Transverse diameter of spinal canal

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
1	3	1	1	1	14.92	13.61	23.84	15.1	13.48	24.5	15.34	14.5	25.71	15.82	14.5	26.77	15.76	16.02	24.05
2		1	1	1	13.97	15.84	21	14.18	15.29	21.85	14.92	14.83	22.43	14.41	14.83	22.46	15.6	15.66	22.41
3		1	1	1	17.33	12.97	23.34	17.93	12.23	23.87	18.51	11.39	25.36	19.57	11.39	25.15	18.24	12.65	23.18
4	2	1	1	1	15.9	15.79	24.54	15.2	15.98	25.45	14.39	17.43	26.79	14.96	17.43	27.46	16.5	17.1	25.24
5		1	1	1	15.91	14.95	21.54	16.58	14.74	23.08	16.06	13.75	23.58	16.78	13.75	23.28	17.4	13.76	22.09
6		1	1	1	16.4	12.81	22.35	16.32	13	23.91	15.75	13.23	23.12	15.14	13.23	24.99	15.64	13.29	22.29
7		1	1	1	14.63	14.85	21.73	15.17	14.51	22.83	15.59	15.2	23.71	16.25	15.2	23.97	15.48	15.6	23.3
8		1	1	1	16.09	13.12	21.98	16.22	12.92	23.02	15.89	13.15	23.81	16.06	13.15	23.7	17.36	13.08	23.83
9		1	1	1	16.4	13.86	23.18	16.4	14.09	25.36	19.23	13.94	26.1	18.49	13.94	26.5	17.48	14.05	27.44
10		1	1	1	17.66	15.34	22.62	17.45	16.21	23.77	17.91	15.97	25.54	16.72	15.97	23.59	17.08	16.6	20.96
11		1	1	1	15.51	15.59	23.81	15.18	15.98	24.73	14.21	17.3	26	14.51	17.3	25.44	14.75	17.1	20.92
12	1	1	1	1	15.56	13.74	22.19	15.76	13.34	22.58	14.62	13.98	23.6	14.91	13.98	24.09	15.21	13.58	24.2
13		1	1	1	16.67	13.74	22.46	17.37	13.1	23.69	17.34	13.41	24.75	17.45	13.41	25.26	16.7	13.82	23.66
14		1	1	1	16.56	12.52	23.88	16.11	12.36	23.72	16.88	14.02	24.79	15.62	14.02	25.54	15.77	15.16	22.72
15		1	1	1	16.78	14.64	22.63	17.98	13.9	22.63	22.46	14.05	24.87	19.09	14.05	22.98	17.36	15.4	19.79
16		1	1	1	15.56	15.38	22.93	16.05	14.98	23.95	15.23	16.67	26.42	15	16.67	24.46	15.2	16.61	21.24
17		1	1	1	16.14	13.65	23.8	18.98	12.88	24.79	17.68	13.64	24.92	15.49	13.64	24.33	15.49	14.39	20.76
18	4	1	1	1	18.42	13.78	23.17	18.29	13.13	24.09	17.62	13.65	24.59	18.15	13.65	25.34	19.82	13.44	24.71
19		1	1	1	15.63	12.72	24.35	19.04	12.41	25.21	16.95	13.74	26.77	16.93	13.74	23.31	16.64	14.73	19.97
20		1	1	1	16.03	17.36	22.32	13.76	16.9	24.27	14.07	15.29	22.43	14.6	15.29	23.73	15.84	14.51	22.2
21		1	1	1	17.8	12.48	22.32	17.63	12.84	24.1	17.12	15.04	25.41	18.55	15.04	25.42	17.61	15.55	25.68
22		1	1	1	16.43	12.86	23.49	16.14	13.54	24.4	15.19	14.08	24.42	15.29	14.08	24.65	15.65	13.74	22.86
23		1	1	1	19.02	12.46	22.72	19.28	12.28	23.54	22.35	11.58	24.13	22.23	11.58	24.9	19.66	12.15	23.88
24		1	1	1	15.96	14.61	21.81	16.91	14.47	22.56	16.11	14.05	23.48	16.56	14.05	23.75	17.75	13.01	22.58
25		1	1	1	15.54	14.2	21.47	17.23	13.7	24.05	23.02	12.88	25.84	20.24	12.88	25.46	19.98	14.19	24.18
26		1	1	1	18.16	13.76	22.75	17.8	12.72	24.23	16.72	14.75	25.5	16.84	14.75	25.48	16.86	15.35	24.76
27	5	1	1	1	17.25	13.63	22.72	18.07	12.52	25.83	18.5	11.72	27.35	19.03	11.72	27.92	18.72	11.11	26.54
28		1	1	1	17.46	14.24	24.7	17.05	14.04	25.76	16.68	13.91	26.64	18.21	13.91	26.43	19.73	12.64	27.1
29		1	1	1	20.11	13.16	25.3	20.42	14.21	25.97	20.19	14.51	25.42	20.04	14.51	25.78	20.38	14.39	21.5
30		1	1	1	19.6	15.3	22.2	18.57	15.34	24.62	18.67	15.37	25.67	17.94	15.37	25.74	16.47	15.85	21.42

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
31	6	1	2	1	18.08	14.82	22.79	17.36	14.14	24.18	17.52	14.54	25.17	18.07	15.45	25.75	18.2	16.49	24.43
32		1	2	1	17.39	14.64	25.06	19.25	13.76	27.1	18.77	14.53	28.46	22.17	14.41	29.27	18.36	15.32	27.59
33		1	2	1	18.03	14.05	23.44	19.64	14.27	25.18	19.18	14.79	25.83	18.03	15.58	26.6	18.3	15.18	24.88
34		1	2	1	16.29	13.84	22.22	18.54	10.41	22.74	17.13	13.92	22.92	16.71	14.29	23.3	16.88	14.13	23.79
35		1	2	1	18.34	13.34	22.74	17.44	13.8	23.99	16.94	14.51	25.09	17.87	13.71	25.07	19.29	13.33	23.93
36	7	1	2	1	16.61	10.45	22.92	16.76	10.63	24.79	17.21	11.88	25.78	19.42	12.58	26.45	17.51	13.73	25.4
37		1	2	1	13.87	14.63	22.89	14.81	14.1	24.73	13.89	14.67	25.87	14.57	14.74	26.24	15.18	15.18	25.62
38		1	2	1	16.71	14.2	23.68	17.45	13.79	24.08	15.36	13.57	24.98	17.65	17.65	24.88	18.24	18.24	24.09
39		1	2	1	17.04	13.42	23.12	17.61	13.14	23.99	18.65	13.79	24.54	20.15	14.14	24.4	20.61	14.86	22.72
40		1	2	1	14.49	13.13	22.44	15.14	13.18	22.76	15.91	13.62	24.98	16.19	13.63	24.73	16.01	23.77	23.77
41		1	2	1	20.7	12.33	23.44	19.54	12.72	23.38	18.05	13.8	23.44	18.45	14.77	23.88	17.94	14.68	23.88
42		1	2	1	17.79	13.83	23.26	15.74	14.24	24.55	16	14.65	24.36	16.81	13.97	25.19	17.29	13.74	22.99
43		1	2	1	15.63	13.89	21.56	16.36	13.01	23.01	20.39	13.29	24.44	20.48	13.33	24.19	17.49	12.91	22.6
44		1	2	1	22.93	11.61	24.34	22.26	10.42	24.77	22.89	11.71	25.9	29.16	11.89	26.9	25.79	12.42	26.67
45		1	2	1	15.05	15.34	22.44	14.02	14.36	22.69	13.21	15.02	22.57	14.86	14.93	24.35	14.9	15.12	25.52
46	8	1	2	1	18.4	14.72	24.3	19.2	13.81	25.26	19.09	14.31	26.02	19.42	14.31	26.55	20.06	14.41	26.52
47		1	2	1	18.01	16.23	25.77	17.76	15.41	27.1	17.52	14.86	28.14	17.85	14.95	28.8	18.16	14.49	25.99
48		1	2	1	16.68	14.93	21.14	16.48	14.59	21.06	15.7	15.04	21.88	16.72	14.9	22.88	16.34	14.51	23.08
49		1	2	1	17.29	14.38	23.23	16.9	12.91	23.53	16.39	13.25	24.47	16.1	13.13	24.53	17.06	13.25	23.54
50		1	2	1	18.95	16.67	23.81	19.75	15.53	24.4	21.91	14.84	25.72	23.01	14.71	26.13	22.21	14.89	26.54
51		1	2	1	16.88	14.99	23.64	17.79	13.97	24.45	17.87	14.44	25.7	20.46	14.59	26.22	21.99	14.8	23.9
52		1	2	1	16.47	15.94	23.66	16.28	15.79	25.66	17.49	15.45	24.78	15.63	15.23	25.9	17.03	15.58	26.29
53		1	2	1	21.16	12.55	27.26	21.13	12.68	29.11	21.69	14.37	30.11	21.38	16.32	29.92	22.62	16.04	29.06
54		1	2	1	17.57	12.89	20.76	18.35	12.46	21.37	16.92	13.07	23.32	15.88	13.19	23.82	16.34	13.11	22.63
55		1	2	1	21.59	10.93	23.57	21.23	10.5	23.75	20.66	11.5	23.65	19.82	11.53	22.91	19.66	11.51	22.58
56		1	2	1	17.44	11.29	25.95	16.68	12.71	23.25	17.63	12.06	25.43	22.08	11.26	27.15	18.66	13.17	25.68
57		1	2	1	16.57	13.8	22.81	16.06	15.06	20.79	17.67	14.21	24.62	16.94	14.6	24.64	16.91	14.86	22.13
58	10	1	2	1	18.64	12.28	23.53	17.93	12.14	24.41	18.45	14.8	23.31	21.37	14.41	24.26	21.6	13.98	24.45
59		1	2	1	16.94	13.28	23.59	18.53	13.52	23.69	19.39	13.71	23.79	18.67	14.86	24.74	21.26	13.3	23.59
60	11	1	2	1	18.05	16.14	23.57	17.96	16.08	23.23	17.94	16.17	24.91	18.44	15.34	25.16	17.57	15.42	23.76

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
61		1	3	1	18.78	11.39	22.9	20.2	10.87	23.11	19.15	11	24.64	22.08	9.88	24.84	22.22	10.79	24.56
62	12	1	3	1	17.99	12.35	21.04	17.96	11.83	21.44	16.42	12.56	21.92	18.01	11.61	20.73	16.93	12.41	21.43
63		1	3	1	16.46	13.94	23.07	17.14	13.89	24.2	16.03	13.9	25.33	18.29	12.6	25.17	17.28	12.58	23.77
64		1	3	1	15.29	14.12	24.02	15.01	14.68	24.68	15.51	14.62	26.21	14.46	14	27.47	16.53	14.25	26.71
65		1	3	1	17.17	15.43	24.64	17.1	14.57	24.13	20.17	14.35	24.49	19.49	14.5	25.59	16.88	15.05	22.61
66		1	3	1	14.94	14.51	21.93	15.79	13.7	24.41	17.99	14.16	26.27	18.96	14.16	26.16	18.81	13.48	25.45
67		1	3	1	18.72	13.38	21.39	19.23	13.67	24.21	20.2	14.73	25.73	21.72	15.62	25.8	21.3	15.07	25.7
68		1	3	1	17.5	15.42	24.5	18.25	13.35	26.04	18.17	14.25	25.79	19.57	14.09	28.35	18.42	15	26.3
69		1	3	1	19.21	13.67	23.02	19.35	14.45	23.79	17.51	13.02	24.08	16.93	14.42	24.24	17.39	14.54	24.03
70	13	1	3	1	18.54	12.96	23.87	17.56	12.85	24.61	18.16	13.01	24.87	17.82	13.2	26.39	17.79	13.91	25.35
71		1	3	1	17.71	13.44	23.84	18.68	11.71	24.45	18.15	12.52	24.47	18.51	13.3	25.13	19.7	13.12	23.61
72		1	3	1	18.71	14.81	24.41	19.13	14.71	26.39	18.4	14.79	27.1	19.77	15.24	27.12	18.82	15.06	27.72
73		1	3	1	14.76	15.21	25.6	15.4	14.02	26.35	15.08	14.94	26.97	16.39	15.11	27.15	15.28	16.15	24.28
74		1	3	1	16.67	16.73	25.6	21.88	15.52	24.9	19.54	16.18	25.93	20.32	15.96	27.06	18.86	16.2	27.6
75		1	3	1	16.8	11.28	20.86	19.11	9.46	23.91	17.14	10.55	24.88	15.71	12.01	23.35	15.41	12.77	20.7
76	13	1	3	1	15.4	13.95	25.6	15.13	14.1	24.9	14.58	14.68	25.93	14.87	14.72	27.06	16.26	14.38	27.6
77		1	3	1	17.98	12.64	23.02	19.61	12.22	24.23	18.45	12.38	24.07	18.86	11.79	24.37	17.31	13.59	23.53
78		1	3	1	14.34	13.97	20.91	13.67	14.08	22.8	13.44	14.02	24.87	13.89	14.19	25.99	14.62	14.26	24.55
79		1	3	1	17.42	13.78	23.03	19.8	13.43	22.81	19.62	14.66	23.83	17.94	15.29	24.22	18.55	14.68	24.14
80		1	3	1	17.57	13.73	22.44	17.04	13.01	23.24	20.69	12.64	23.09	21.26	13.12	23.3	16.93	13.66	23.59
81		1	3	1	17.13	12.58	21.17	20.54	11.6	22.61	17.78	13.02	22.85	16.8	14.13	23.24	17.32	14.63	23.06
82		1	3	1	16.14	12.91	22.28	15.98	12.81	23.99	16.87	13.38	24.82	16.53	14.4	25.88	15.55	14.19	26.05
83		1	3	1	17.27	12.06	22.39	18.78	12.1	23.39	16.79	12.34	24.35	18.02	11.48	25.34	16.82	12.59	24.57
84		1	3	1	15.91	15.21	24.64	15.97	14.04	25.64	17.84	13.82	27.68	18.76	13.01	27.59	18.82	14.23	27.18
85		1	3	1	15.62	15.37	23.34	15.68	14.54	24.06	15.38	14.71	24.57	16.97	14.9	24.57	15.97	16.29	24.71
86		1	3	1	17.37	14.77	25.51	16.95	14.52	26.23	18.12	14.38	27.06	16.84	15.71	27.29	16.79	16.21	26.16
87		1	3	1	16.48	12.97	23.89	16.3	12.45	24.57	16.39	12.63	26.5	17.29	13.09	28.1	18.27	13.15	26.15
88		1	3	1	14.97	14.17	22.3	14.93	13.52	23.59	14.41	14.64	24.15	17.2	13.11	24.92	17.7	13.25	24.6
89		1	3	1	17.1	12.05	24.35	15.95	12.87	23.94	18.9	14.09	25.55	23.45	13.44	24.7	24.4	11.53	26.79
90		1	3	1	16.42	13.34	24.1	17.48	12.79	24.33	16.75	12.4	25.24	16.05	13.35	26.23	16.3	15.15	24.25

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
91		1	1	2	16.59	12.41	21.35	16.27	12.29	22.89	14.91	12.55	23.46	15.4	12.85	22.73	16.3	12.03	23.16
92		1	1	2	13.18	15.19	19.93	13.85	14.93	20.55	13.83	14.99	21.97	14.3	14.54	21.75	14.02	15.08	20.32
93	16	1	1	2	15.06	15.5	23.71	14.93	16.07	25.18	15.34	15.33	24.84	16.32	15.11	24.44	17.5	14.18	24.62
94		1	1	2	16.13	15.14	22.49	15.84	14.64	23.73	15.95	14.19	24.65	16.35	13.9	25.23	16.37	13.35	23.61
95		1	1	2	15.31	14.62	20.77	14.51	14.56	22.08	13.33	14.42	23.53	13.48	14.73	22.9	14.04	14.65	20.84
96		1	1	2	14.32	13.6	20.89	14.43	13.05	21.84	15.12	13.56	22.17	15.58	13.09	22.64	15.08	12.85	22.12
97		1	1	2	11.68	14.99	21.88	11.94	14.3	21.04	12.26	14.25	21.73	13.29	13.4	21.82	13.25	12.96	21.14
98		1	1	2	14.14	16.17	21.52	13.76	15.89	22.77	14.09	15.28	23.26	15.12	13.56	24.52	14.52	14.28	22.5
99		1	1	2	16.43	12.9	22.54	15.05	13.33	19.98	14.52	13.34	20.12	15.24	12.7	20.91	16.38	12.33	20.23
100	17	1	1	2	16.19	12.81	21.88	16.23	12.47	23.05	15.58	13.56	23.19	17.6	13.85	24.65	17.66	13.83	23.27
101		1	1	2	16.03	14.18	21.97	15.99	14.41	22.77	15.47	14.45	23.24	15.84	14.89	23.18	15.74	15.25	21.94
102		1	1	2	17.88	15.06	21.8	17.22	15.45	23.2	17.01	14.99	24.34	17.01	14.23	25.03	16.95	13.86	23.34
103		1	1	2	16.24	12.62	21.24	15.71	13.51	22.08	15.04	13.94	22.92	15.04	13.97	23.07	14.75	13.68	23.26
104		1	1	2	15.91	13.14	22.53	16.86	12.7	22.73	15.66	14.07	23.76	15.57	14.65	23.31	15.84	14.04	23.23
105	18	1	1	2	13.85	13.94	20.74	14.12	13.57	22.46	14.08	13.89	24.17	14.47	13.58	24.53	15.13	13.29	23.45
106		1	1	2	14.93	15.84	23.51	15.05	16.13	24.83	14.99	16.55	25.66	15.39	16.74	24.86	14.18	15.98	22.99
107		1	1	2	15.76	14.22	23.78	15.44	14.81	24.74	15.29	15.13	25.51	16.11	15.08	26.32	15.66	14.2	23.65
108		1	1	2	15.81	14.25	22.06	14.78	14.57	23.52	13.61	15.33	23.65	13.53	15.39	23.82	15.14	14.6	23.06
109		1	1	2	17.24	11.83	23.22	17.63	11.34	24.12	19.04	10.52	24.24	18.83	10.43	25.05	18.2	10.99	23.29
110		1	1	2	15.11	13.91	20.22	14.78	13.86	21.46	13.72	14.54	22.99	15.04	13.81	23.8	15.45	12.9	23.17
111		1	1	2	14.13	14.11	21.24	15.25	13.77	22.41	14.86	14.33	22.88	15.72	14.86	22.49	16.38	14.22	22
112	19	1	1	2	15.13	15.22	23.33	14.55	15.22	23.38	14.85	15.91	25.05	16.87	15.42	25.39	17.81	14.05	24.33
113		1	1	2	14.26	14.67	21.41	14.49	14.72	23.19	14.82	14.14	25.43	15.91	14.04	25.78	15.44	13.81	24.51
114		1	1	2	14.21	15.5	21.33	15.15	14.63	22.3	14.18	14.61	23.35	14.44	14.32	23.5	14.36	14.75	21.99
115		1	1	2	15.74	12.92	21.3	15.41	11.55	23.89	14.55	12.54	23.59	15.47	12.6	23.8	15.17	12.92	23.14
116	20	1	1	2	17.73	13.31	23.11	17.77	13.27	24.22	16.67	13.66	25.45	15.58	13.59	26.07	14.99	13.36	23.49
117		1	1	2	13.48	13.47	20.15	14.42	12.91	21.72	14.08	13.38	21.54	14.17	13.6	21.28	14.93	13.28	21.07
118		1	1	2	15	13.39	24.07	14.96	12.88	25.32	15.53	13.64	26.81	16.48	13.56	27.68	16.68	14.04	25.49
119		1	1	2	14.95	13.14	22.09	14.69	12.23	23.15	13.91	13.26	23.53	15.42	13.01	24.5	16.19	13.73	23.2

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
120		1	2	2	16.76	15.6	23.27	17.4	13.67	24.05	16.68	13.97	25.87	20.32	14.31	25.81	18.23	13.66	23.98
121		1	2	2	14.89	15.42	23.24	15.01	13.91	24.21	14.59	14.89	25.62	15.74	15.4	25.62	16.86	15.18	23.61
122		1	2	2	13.48	15.87	21.35	13.82	15.06	22.55	13.12	15.76	23.26	13.77	15.88	23.97	15.04	15.93	23.43
123		1	2	2	17.11	12.14	22.87	16.14	12.03	23.69	15.75	12.14	23.94	17.92	11.39	24.1	18.48	11.39	23.1
124		1	2	2	13.81	13.36	22.01	14.49	13.48	23.49	14.38	13.5	24.68	15.4	13.59	25.9	15.04	14.26	23.42
125		1	2	2	15.58	13.49	22.16	15.41	12.66	22.37	15.42	12.84	23.71	15.83	12.1	24.99	15.62	12.15	23.63
126		1	2	2	15.31	12.9	21.19	15.15	13.11	23.08	15.61	13.53	23.91	17.31	13.93	25.13	15.69	13.94	24.56
127		1	2	2	16.88	13.41	21.9	16.17	13.77	21.83	16.17	13.69	21.89	15.88	13.86	22.58	16.12	13.29	22.02
128		1	2	2	14.64	17.03	21.47	13.67	17.41	22.15	13.41	17.04	23.72	14.48	17.29	25.14	15.79	16.51	27.65
129		1	2	2	22	12.29	23.56	17.43	12.98	22.59	23.71	12.27	25.51	23.03	12.61	25.12	20.04	12.34	23.18
130	21	1	2	2	13.6	15.18	21.14	13.53	14.27	21.63	13.41	14.02	23.81	15.5	13.95	25.64	15.77	13.65	23.77
131		1	2	2	16.38	14.4	20.96	18.72	13.22	22.22	16.2	14.89	21.71	14.98	14.88	24.61	16.36	14.64	22.93
132		1	2	2	16.27	13.61	22.57	16.81	12.5	23.29	18.15	12.85	23.24	21.11	11.92	23.68	16.69	13.24	23.91
133		1	2	2	15.58	14.37	23.1	16.31	13.94	23.77	16.38	12.94	25.77	17.49	13.05	25.59	19.96	13.04	24.45
134		1	2	2	14.28	13.88	21.79	14.14	13.63	22.9	13.51	13.33	22.85	13.85	13.36	22.58	14.94	13.19	22.46
135		1	2	2	17.53	12.85	23.76	17.7	12.2	25.4	18.23	12.88	25.38	18.69	13.13	25.46	19.06	14.38	25.01
136		1	2	2	14.06	14.5	22.75	13.68	14.47	24.64	14.17	15.05	25.08	14.52	14.88	25.33	15.1	14.94	23.71
137	22	1	2	2	13.27	13.55	22.02	13.31	12.87	23.54	13.93	13.29	24.6	15.55	13.16	24.91	15.49	12.77	24.55
138		1	2	2	14.99	14.84	23.09	14.45	14.43	24.05	13.62	14.9	25.93	14.52	14.84	26.07	15.23	14.51	24.28
139	23	1	2	2	13.88	13.22	22.77	13.56	12.63	22.65	12.89	12.49	23.5	14.87	12.59	24.82	14.46	12.47	23.56
140		1	2	2	14.42	15.07	22.87	14.74	13.58	24.78	14.48	13.66	26.71	15.49	13.26	26.79	15.94	13.62	25.85
141		1	2	2	15.4	12.84	20.76	14.5	12.72	22.1	14.46	12.6	23.78	15.96	12.68	24.32	17.85	12.1	22.66
142	24	1	2	2	14.86	15.05	22.55	15.64	14.86	22.75	15.81	14.7	23.08	14.58	15.34	23.63	14.57	15.23	22.75
143		1	2	2	17.17	11.05	20.64	19.2	12.5	21.98	23.51	12.93	23.98	24.29	12.91	24.53	21.05	13.13	24.36
144		1	2	2	14.71	13.62	21.56	15.04	13.97	21.53	15	14.49	21.59	16.05	14.44	21.93	15.96	14.53	20.77
145		1	2	2	17.2	12	24.02	16.9	12.72	25.55	15.99	13.69	25.41	19.02	13.07	25.47	18.49	12.58	25.05
146		1	2	2	16.12	13.45	22.41	15.58	14.65	24.33	15.97	14.96	25.08	16.07	13.98	24.29	17.62	12.38	22.31
147		1	2	2	17.22	13.96	22.24	15.75	14.67	22.83	14.9	15.42	23.99	14.6	14.44	24.25	15.48	15.01	21.81
148		1	2	2	16.25	14.22	23.43	15.58	14.53	23.67	14.66	14.67	24.41	14.62	14.51	24.81	15.28	13.86	23.9
149	25	1	2	2	16.39	14.3	22.32	15.95	14.32	23.08	14.71	14.59	24.26	15.79	14.55	23.43	16.81	14.86	22.07
150		1	2	2	15.1	13.62	21.96	13.63	12.22	23.77	13.71	12.48	25.26	14.64	12.8	26.25	14.49	13.42	25.94

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
151		1	3	2	12.97	14.54	19.95	12.01	14.63	20.08	11.93	15.19	22.51	12.09	14.79	21.79	13.04	14.21	21.57
152		1	3	2	14.25	15.14	24.8	13.78	15.69	23.46	13.64	15.5	24.86	15.06	14.06	25.6	15.22	14.86	23.71
153	26	1	3	2	13.74	12.7	22.07	13.8	13.25	21.06	14.53	12.58	22.64	14.35	13.09	22.5	14.13	12.97	20.63
154		1	3	2	15.07	14.98	23.58	15.47	15.04	24.62	16.72	13.99	24.76	18.88	13.36	25.87	20.95	12.29	24.74
155	27	1	3	2	13.69	15.91	21.37	15.07	16.29	21.75	14.38	15.71	23.8	15.65	15.95	24.59	16.07	15.73	24.75
156		1	3	2	15.67	12.9	23.75	15.66	13.16	23.94	18.51	13.2	24.84	15.78	10.75	25.05	16.78	12.85	23.71
157		1	3	2	17.38	11.58	23.26	17.29	11.71	24.41	19.71	11.42	24.72	20.92	11.83	24.38	18.66	13.09	22.43
158		1	3	2	17.49	11.96	24.7	17.33	11.8	25.7	18.14	12.12	25.65	19.13	12.43	26.81	20.13	12.54	24.27
159		1	3	2	15.47	15.2	22.14	15.24	15.81	23.88	14.72	15.83	24.84	17.29	14.83	24.13	16.83	14.11	22.23
160		1	3	2	16.11	14.44	21.09	15.76	14.08	24.45	15.83	14.48	24.06	16.91	14.49	24.43	16.59	14	22.46
161		1	3	2	20.24	12.1	23.45	19.33	12.15	25.36	18.48	11.98	26.57	17.51	12.98	25.85	17.2	14.29	26.02
162		1	3	2	13.74	12.44	22.58	14.63	11.78	23.76	15.98	12.01	23.93	16.15	12.48	22.95	15.28	13.01	19.88
163		1	3	2	14.94	15.83	20.98	14.27	14.59	21.47	14.85	15.04	22.39	16.51	15.16	25.75	14.09	16.27	25.46
164		1	3	2	15.92	15.31	23.06	17.78	13.12	24.19	16.91	12.84	25.15	19.53	12.15	26.77	20.46	12.38	27.5
165		1	3	2	15.39	13.85	21.81	15.94	12.82	23.55	18.55	11.97	24.3	15.74	13.59	24.54	15.5	13.06	24.09
166		1	3	2	15.49	14.34	20.52	17.34	13.78	22.62	16.51	13.46	23.46	17.76	13.29	22.92	14.77	13.06	20.72
167	28	1	3	2	16.57	13.59	21.59	17.74	14.33	23.21	18.07	14.4	24.83	18.64	13.47	25.23	18.56	13.54	24.07
168		1	3	2	16.5	18.03	23.75	15.54	16.35	23.59	15.62	15.36	23.95	16.42	14.53	25.15	16.1	14.35	24.15
169	29	1	3	2	13.61	11.9	20.33	13.68	11.7	20.72	16.14	9.85	23.83	16.35	11.61	23.41	17.59	11.2	22.64
170		1	3	2	16.69	14.55	22.82	19.35	13.05	24.26	19.69	13.45	26.36	18.41	14.31	25.29	16.93	14.12	25.53
171		1	3	2	15.92	13.62	22.31	15.64	13.95	23.73	15.64	14.37	24.37	20.47	13.71	24.41	18.47	12.74	24.76
172		1	3	2	13.46	15.2	23.05	12.76	14.84	23.68	11.99	15.41	24.64	11.73	16.28	25.5	11.55	16.77	26.78
173		1	3	2	17.3	13.38	22.13	15.48	12.51	22.77	16.85	11.47	22.83	15.48	12.33	24.23	15.46	13.68	23.04
174		1	3	2	13.62	14.36	20.36	14.05	14.07	21.2	15.92	13.52	22.04	18.9	11.66	22.4	17.02	11.68	21.93
175		1	3	2	12	13.97	21.93	13.68	13.51	23.26	13.65	14.04	23.41	13.25	15.14	23.12	13.58	15.18	22.39
176		1	3	2	13.93	13.46	22.73	14.7	12.54	23.46	15.03	12.66	23.64	14.95	12.59	23.75	15.43	13.12	21.55
177		1	3	2	16.96	13.18	22.59	20.01	11.88	24.83	18.08	13.06	25.62	19.27	13.64	26.07	19.75	14.3	25.53
178		1	3	2	16.81	14.24	24.48	17.24	13.58	24.56	17.3	14.04	24.46	17.69	14.54	25.11	18.12	14.16	24.05
179	30	1	3	2	14	14.71	22.82	13.5	14.33	23.74	13.51	15.43	23.75	14.21	15.73	24.38	14.04	15.84	24.97

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
1	3	2	1	1	14.97	13.67	23.94	14.85	13.92	25.76	14.95	13.68	24.49	15.78	14.68	26.64	15.73	16.17	24.17
2		2	1	1	13.86	15.89	21.11	14.03	15.29	21.57	14.82	14.98	22.41	14.48	15.16	22.87	15.52	15.43	22.3
3		2	1	1	17.41	12.9	23.39	17.84	12.5	24.26	18.44	12.05	25.22	19.61	11.7	24.75	18.22	12.67	23.04
4	2	2	1	1	15.81	15.83	24.53	15.37	16.04	25.3	14.13	17.13	26.57	15.22	17.29	27.33	16.75	17.1	25.29
5		2	1	1	16.07	14.79	21.56	16.69	14.54	23.11	16.38	15.15	23.7	16.68	13.97	23	17.31	13.69	22.07
6		2	1	1	16.56	12.76	22.3	16.45	12.9	24.04	15.57	13.16	23.17	15.45	13.42	25	15.8	13.5	22.15
7		2	1	1	14.24	14.77	21.78	15.22	14.38	22.8	15.36	14.94	23.64	16.23	15.37	24.31	15.37	15.62	23.33
8		2	1	1	16.15	13.19	21.99	16.15	12.88	22.94	15.53	13.4	23.87	15.99	12.89	23.68	17.29	13.06	23.73
9		2	1	1	16.08	13.81	23.06	16.81	14.04	25.37	19.29	13.37	26.08	18.55	13.84	26.52	17.49	14.07	27.29
10		2	1	1	17.42	15.28	22.83	17.42	16.14	23.67	17.99	15.86	25.09	16.51	15.96	23.74	16.83	16.66	20.82
11		2	1	1	15.51	15.59	24.03	14.92	16.04	24.61	14.32	17.14	26.12	14.75	17.16	25.44	14.59	17.04	21.26
12	1	2	1	1	15.21	13.48	22.35	15.84	13.29	23.3	14.5	14.08	23.59	14.86	14.03	24.15	15.29	13.54	24.14
13		2	1	1	16.72	13.67	22.23	17.38	13.02	24.08	16.99	12.91	24.83	17.43	13.51	25.12	16.65	13.79	23.72
14		2	1	1	16.73	12.52	23.62	16.25	12.36	23.67	17.05	13.05	24.48	15.72	13.98	25.44	15.7	15.12	22.74
15		2	1	1	16.78	14.68	22.58	18.3	13.74	23.84	22.33	13.89	24.7	18.89	14.33	23	17.44	15.44	19.89
16		2	1	1	15.58	15.3	22.87	15.99	15.17	23.8	15.24	15.87	26.39	14.87	16.37	24.13	15.09	16.46	21.17
17		2	1	1	16.41	13.93	24.06	18.69	12.84	24.43	17.65	11.39	25.3	15.39	13.52	24.01	15.21	14.46	20.7
18	4	2	1	1	18.74	14	23.14	18.31	13.18	24.02	17.46	13.48	24.69	18	13.51	25.27	19.84	13.4	24.53
19		2	1	1	15.86	12.91	24.34	19.18	12.04	25.39	17.01	13.83	26.75	16.68	13.83	23.1	16.37	14.83	19.91
20		2	1	1	15.95	17.35	22.12	13.78	17.05	24.27	14.23	15.8	22.44	14.53	15.19	24.03	15.94	14.68	22.1
21		2	1	1	17.55	12.51	22.38	17.89	12.8	24.08	17.05	14.36	25.39	18.67	14.87	25.46	17.64	15.36	25.6
22		2	1	1	16.2	12.63	23.54	15.91	13.48	24.24	15.23	14.13	24.68	15.44	13.97	24.99	15.46	13.89	22.9
23		2	1	1	18.99	12.25	22.74	19.33	12.42	23.4	22.5	12.47	24.65	21.89	11.53	24.75	19.8	12.24	23.72
24		2	1	1	16.18	14.47	21.93	16.59	14.47	22.44	16.19	14.38	23.61	16.29	14.38	23.47	17.59	12.87	22.41
25		2	1	1	15.51	14.37	21.7	17.39	14.03	24.21	22.31	13.54	25.73	20.59	12.76	25.8	19.88	13.97	24.53
26		2	1	1	18.19	13.78	22.7	17.89	12.78	24.37	16.48	13.89	25.41	16.71	14.47	25.53	16.95	15.16	24.77
27	5	2	1	1	17.51	13.59	22.87	18.11	12.9	25.92	18.22	12.12	27.28	19.11	11.49	27.88	18.52	11.02	26.43
28		2	1	1	17.66	14.29	24.87	17.03	13.92	25.61	16.55	14.16	26.56	18.08	13.62	26.61	19.86	12.72	27.18
29		2	1	1	20.01	13.45	25.33	20.36	14.2	26.31	20.28	14.36	25.44	19.73	14.26	25.78	20.16	14.67	21.49
30		2	1	1	19.76	15.03	22.41	18.63	15.47	24.63	18.91	15.71	25.88	17.68	15.75	25.7	16.48	15.86	21.35

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
31	6	2	2	1	17.95	14.97	22.56	17.4	14.44	24.02	17.75	14.74	25.39	17.97	15.62	25.97	18.16	16.86	24.09
32		2	2	1	16.79	14.71	25.15	19.26	13.88	27.09	18.89	14.56	28.53	21.96	13.74	29.14	18.31	15.17	27.65
33		2	2	1	18.21	13.8	23.15	19.93	14.31	25.18	19.2	14.7	25.84	18.31	15.6	26.55	18.03	15.05	24.92
34		2	2	1	16.68	13.71	22.23	18.52	10.56	22.75	17.17	14.4	23.02	16.5	14.17	23.49	16.77	14.06	23.77
35		2	2	1	18.53	13.24	22.82	17.11	13.63	24.05	17.37	14.34	25.03	17.89	13.81	25.16	19.45	14.09	23.85
36	7	2	2	1	16.62	10.61	23.28	16.49	10.85	25.14	17.56	11.8	25.79	19.34	12.7	26.27	17.48	13.8	25.41
37		2	2	1	13.88	14.63	23.21	14.38	14.05	24.73	14.03	14.87	25.89	14.48	14.56	26.48	15.21	15.24	25.57
38		2	2	1	16.33	13.58	23.54	17.51	13.71	23.99	15.54	13.71	25.17	17.52	17.52	25.2	18.13	18.13	24.06
39		2	2	1	17.09	13.53	23.06	17.93	13.04	23.93	18.59	13.59	24.58	20.48	14.26	24.47	20.68	14.78	22.73
40		2	2	1	14.61	13.1	23.47	15.03	13.33	22.84	15.7	13.59	24.89	16.09	13.62	24.73	15.8	23.78	23.81
41		2	2	1	20.77	12.11	23.49	19.23	12.7	23.4	18.25	13.92	23.5	18.74	14.53	23.5	17.96	14.83	23.75
42		2	2	1	17.51	13.71	23.48	15.91	14.12	24.69	16.02	14.63	24.51	16.61	14.14	25.18	17.35	13.93	22.84
43		2	2	1	15.64	13.78	21.52	16.08	12.81	23.18	20.09	13.15	24.37	20.36	13.61	24.2	17.32	13.13	22.74
44		2	2	1	22.64	11.47	24.08	22.61	10.27	24.8	22.58	11.68	25.82	28.73	11.9	26.86	25.57	12.44	26.3
45		2	2	1	14.8	15.08	22.28	14.18	14.48	22.68	13.54	15.13	22.51	14.91	15.26	24.38	14.53	14.83	25.59
46	8	2	2	1	18.48	14.47	24.11	18.98	13.59	25.02	19.23	14.41	25.74	19.22	14.74	26.9	19.98	14.07	26.48
47		2	2	1	18.04	16.28	25.74	17.62	15.37	26.98	17.55	14.77	28.2	17.51	15.04	28.67	17.87	14.5	26.21
48		2	2	1	16.59	14.91	21.03	16.54	14.4	21.06	15.69	15.15	21.95	17.05	14.76	22.49	16.41	14.44	23.31
49		2	2	1	17.25	14.2	23	16.63	12.69	23.83	16.27	13.13	24.38	16.07	13.38	24.82	17.02	13.38	23.85
50		2	2	1	19.06	16.74	24.23	19.72	15.52	24.32	21.63	14.91	25.61	22.74	14.92	26.31	22.26	14.9	26.55
51		2	2	1	16.81	15.01	23.41	18.13	14.16	24.56	17.77	14.64	25.72	20.38	14.98	25.96	22.01	14.8	23.84
52		2	2	1	16.53	15.88	23.85	16.38	15.91	25.5	17.44	15.41	24.6	15.78	15.07	26.17	17.09	15.87	26.33
53		2	2	1	21.06	12.59	27.25	21.18	12.75	29.21	21.69	14.56	20.01	21.3	16.2	29.72	22.62	16.32	29.12
54		2	2	1	17.23	12.88	20.94	18.08	12.27	21.39	17.07	13.27	23.36	15.88	12.81	24.04	16.4	13.04	22.52
55		2	2	1	21.84	11.07	23.4	21.57	10.39	23.57	20.84	11.29	23.74	19.91	11.32	22.92	19.5	11.71	22.24
56		2	2	1	17.48	11.38	25.51	16.59	12.71	23.04	17.7	12.18	25.83	22.16	11.65	26.92	18.96	12.83	25.74
57		2	2	1	16.68	14.07	22.8	16.29	15.42	20.82	17.48	14.41	24.93	16.56	14.49	24.75	16.64	15.02	22.17
58	10	2	2	1	18.31	12.27	23.6	17.65	12.14	24.14	18.55	14.85	23.65	21.4	14.4	24.1	21.96	14.04	24.81
59		2	2	1	16.93	13.3	23.26	18.47	13.19	23.87	19.23	14.01	23.89	18.67	14.58	24.81	21.59	13.1	23.53
60	11	2	2	1	17.9	16.14	23.52	17.92	16.05	23.13	18.21	16.33	24.87	18.07	15.33	24.75	17.55	15.04	23.8

ID	Idln	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
61		2	3	1	18.64	11.52	22.72	19.89	10.8	23.51	18.81	11.32	24.71	22.06	10.04	24.79	22.31	10.66	24.47
62	12	2	3	1	17.7	12.61	20.97	18.26	11.73	21.59	16.58	12.58	21.99	17.98	11.87	20.48	17.11	12.09	21.81
63		2	3	1	16.33	13.98	23.26	17.13	13.65	24.02	16.11	13.98	25.15	18.17	12.56	25.49	17.17	12.45	23.66
64		2	3	1	15.01	14.13	23.91	14.9	14.75	24.17	15.83	14.73	26.11	16.49	13.75	27.46	16.68	14.06	26.82
65		2	3	1	16.96	15.8	24.65	17.1	14.52	24.29	19.82	14.73	24.51	19.47	14.45	25.82	16.73	14.9	22.63
66		2	3	1	14.78	14.73	21.8	15.49	13.61	24.27	17.93	14.44	26.35	19.36	14.2	26.32	19.09	13.5	25.22
67		2	3	1	18.42	13.78	21.21	19.55	13.66	23.88	20.3	14.45	25.34	21.73	15.54	25.82	21.12	14.96	25.78
68		2	3	1	17.58	15.21	24.29	18.24	13.3	25.89	17.78	14.32	25.75	19.73	13.73	28.34	18.37	14.64	26
69		2	3	1	19.13	13.43	22.89	19.48	14.48	23.87	17.45	13.05	23.85	16.69	14.45	24.34	17.36	14.16	24.21
70	13	2	3	1	18.27	12.73	23.83	17.54	12.69	24.67	17.82	13.05	24.96	17.81	13.21	26.4	17.71	13.76	25.4
71		2	3	1	17.9	13.72	23.84	18.94	11.61	24.59	17.98	12.66	25.07	18.12	13.06	25.22	19.58	13.21	23.71
72		2	3	1	18.52	14.63	24.71	19.31	14.95	26.23	18.41	14.92	27.1	19.52	15.45	27.1	18.6	15.16	27.66
73		2	3	1	14.79	15.13	25.33	15.22	14.19	26.31	14.83	14.63	27.02	16.26	14.9	27.05	15.39	15.78	24.17
74		2	3	1	16.67	16.89	25.65	21.86	15.49	24.92	20.06	15.74	25.88	20.4	15.63	27.08	18.58	16.5	27.55
75		2	3	1	16.58	11.32	20.79	19.29	9.84	23.72	10.55	10.4	24.58	12.01	11.71	23.38	12.77	12.88	20.74
76	13	2	3	1	15.29	14.1	25.65	15.15	14.11	24.92	14.79	14.58	25.88	14.9	14.63	27.08	16.25	14.57	27.55
77		2	3	1	12.64	12.72	22.93	19.46	12.22	24.19	18.06	12.15	23.96	19.14	12.05	24.61	17.26	13.63	23.21
78		2	3	1	14.7	14.33	21.31	13.28	14.03	22.68	13.44	14.04	24.56	13.6	14.29	26.21	14.23	14.34	24.47
79		2	3	1	17.33	13.83	22.98	19.4	13.68	22.43	19.49	14.92	24.12	18.17	14.9	24.2	18.34	14.6	24.3
80		2	3	1	17.17	14.11	22.14	16.74	12.9	23.23	20.84	13.32	23.41	21.12	13.32	23.6	17.1	13.64	23.79
81		2	3	1	17.35	12.2	21.13	20.45	11.42	22.63	17.97	13.21	22.52	16.82	14.17	23.47	17.7	14.66	23.37
82		2	3	1	16.34	12.71	22.43	16.06	12.69	24.06	16.48	13.47	24.77	16.59	14.54	25.85	15.93	14.13	26.07
83		2	3	1	16.95	12.3	22.36	18.61	12.17	23.27	16.74	12.14	24.06	18.23	11.14	25.1	16.96	12.79	24.25
84		2	3	1	16.02	15.42	24.56	16.34	14.11	25.66	17.81	14.14	27.59	18.84	13.37	27.22	18.76	14.14	26.78
85		2	3	1	15.83	15.13	23.23	15.66	14.8	24.12	15.36	14.77	24.3	16.94	14.66	25.05	15.94	15.99	24.8
86		2	3	1	17.02	14.73	25.42	16.83	14.62	26.37	17.99	14.44	27.2	16.97	15.71	27.16	17.15	16.19	26.36
87		2	3	1	16.42	12.57	24.12	16.18	12.45	24.49	16.19	12.26	26.56	17.23	13.07	28.11	18.57	12.87	26.08
88		2	3	1	15.06	14.5	22.42	14.85	13.35	23.53	14.42	14.24	24.13	17.14	13.1	25.19	17.93	13.17	24.29
89		2	3	1	17.14	12.03	24.32	16.16	13.14	24.16	18.84	13.86	25.8	23.44	13.4	24.73	24	11.57	27.08
90		2	3	1	16.26	13.37	24.09	17.45	12.7	24.36	16.76	12.25	25.51	16.41	13.46	26.49	16.62	14.99	24.16

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
91		2	1	2	16.43	12.47	21.2	16.27	12.6	22.9	14.71	12.94	23.24	15.38	12.94	22.69	16.15	12.17	23.12
92		2	1	2	13	15.27	19.8	13.95	15.27	20.61	13.86	15.11	20.94	14.33	14.5	21.58	13.96	14.88	20.12
93	16	2	1	2	14.85	15.46	23.7	14.84	15.71	25.11	15.38	15.52	24.85	16.22	15.21	24.77	17.53	14.71	24.73
94		2	1	2	16.08	14.95	22.54	15.94	14.47	23.77	15.84	14.08	24.56	16.55	13.83	25.36	16.3	13.22	23.57
95		2	1	2	15.42	14.77	20.8	14.12	14.29	22.04	13.66	14.52	23.43	13.63	14.84	23.06	14.22	14.57	20.74
96		2	1	2	14.5	13.71	21.04	14.55	13.03	21.87	15.13	13.59	22.19	15.46	13.24	22.55	15.11	12.56	22.34
97		2	1	2	12.01	15.08	21.83	12.08	14.21	21.29	12.11	14.56	21.52	13.3	13.59	21.84	13.44	12.92	21.05
98		2	1	2	13.81	16.31	21.64	13.77	15.89	22.53	14.44	15.16	23.29	14.85	13.92	24.65	14.43	14.45	22.58
99		2	1	2	16.8	12.78	22.5	15.16	13.47	20.33	14.56	13.59	19.89	15.18	12.65	20.97	16.38	12.27	20.19
100	17	2	1	2	16.18	12.84	22.09	15.36	12.75	22.82	15.47	13.45	23.27	17.75	13.79	24.76	17.78	13.62	23.28
101		2	1	2	16.41	14.3	22.03	16.09	14.2	23.08	15.51	14.67	23.05	15.85	15.17	23.01	15.38	15.09	21.92
102		2	1	2	17.8	15.24	21.86	17.24	15.54	23.34	17.32	15.09	24.46	17.41	14.37	25.07	16.66	13.92	23.12
103		2	1	2	16.13	13.1	21.44	15.63	13.33	22	15.02	14.3	22.81	15.37	13.67	23.13	15.05	13.66	23.27
104		2	1	2	16.23	13.11	22.56	16.54	12.72	22.81	15.77	14.22	23.79	15.32	14.8	23.43	15.79	14.36	23.26
105	18	2	1	2	13.89	13.96	20.86	13.7	14.11	22.75	13.77	13.93	24.03	14.51	13.72	24.51	14.89	13.49	23.47
106		2	1	2	15.21	15.81	23.49	15.01	16.2	25.08	15.01	16.86	25.59	15.51	16.55	25.01	14.35	16.05	23.05
107		2	1	2	16.09	14.48	23.66	15.32	14.9	24.77	15.41	15.08	25.92	16.01	14.95	23.6	15.52	14.4	23.76
108		2	1	2	15.86	14.32	22.24	14.91	14.59	23.5	13.72	15.41	23.96	13.65	15.41	23.72	15.19	14.65	23.05
109		2	1	2	16.98	12.11	23.07	17.5	11.41	24.19	19.15	10.43	24.05	18.92	10.57	24.89	18.25	11.04	23.3
110		2	1	2	14.9	14.12	20.51	14.69	13.89	21.77	13.93	14.5	23.12	14.77	13.95	23.91	15.25	12.7	23.46
111		2	1	2	13.95	14.27	21.36	15.4	13.78	22.33	15	14.08	22.67	15.72	14.52	22.73	16.07	13.91	21.96
112	19	2	1	2	15.24	15.62	23.11	14.83	15.02	23.06	15.01	15.61	25.15	16.59	15.1	25.43	18.11	14.32	24.15
113		2	1	2	14.44	14.36	21.54	14.44	14.83	23.22	14.56	14.12	25.63	15.98	14.06	25.84	15.43	13.94	24.49
114		2	1	2	14.15	15.47	21.11	15.06	14.65	22.36	14.23	14.42	23.22	14.3	14.42	23.54	14.35	14.6	22.02
115		2	1	2	15.93	12.91	21.08	15.5	11.93	23.47	14.31	12.38	24.52	15.72	12.73	23.78	15.11	13.17	23.09
116	20	2	1	2	17.45	13.09	22.99	18.02	13.49	24.42	16.67	13.88	25.33	15.33	13.62	26.17	14.89	13.76	23.51
117		2	1	2	13.91	13.65	20.16	14.39	12.93	21.61	13.97	12.98	22.31	14.05	13.35	21.53	14.8	13.21	21.05
118		2	1	2	15.13	13.18	23.92	14.69	13.03	25.5	15.82	13.46	26.88	16.41	13.2	27.57	16.68	13.79	25.15
119		2	1	2	14.99	12.74	22.11	14.48	12.41	22.97	13.97	12.85	23.51	15.62	12.88	24.29	16.26	13.68	23.14

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
120		2	2	2	16.41	15.63	23.2	17.64	13.56	24.06	16.84	14.14	25.86	20.02	14.13	25.71	18.34	13.7	24.02
121		2	2	2	15.06	15.38	23.22	15.26	14.25	24.5	14.21	15.02	25.9	15.78	15.47	25.99	16.56	15.44	23.46
122		2	2	2	13.79	15.71	21.34	13.54	15.26	22.42	13.34	15.84	23.24	13.83	15.97	24.03	14.85	16.01	23.61
123		2	2	2	17.11	11.98	22.64	15.95	12.11	23.66	15.74	11.69	24.14	18.05	11.39	24.11	18.41	11.88	23.03
124		2	2	2	14.06	13.54	22.24	14.24	13.47	23.57	14.51	13.45	24.7	15.63	13.64	25.73	14.98	14.51	23.42
125		2	2	2	15.85	13.24	22.16	15.32	12.43	22.51	15.74	12.81	23.83	15.84	12.33	24.97	15.76	12.39	23.73
126		2	2	2	15.69	12.92	21.2	14.88	13.01	23.15	15.39	13.8	24.27	17.14	14.06	24.55	15.36	14.03	24.3
127		2	2	2	17.1	13.19	22.08	16.01	13.95	21.94	16.29	13.87	21.9	16.01	15.15	22.38	15.73	13.68	22.25
128		2	2	2	15.07	16.83	21.36	13.97	17.43	22.33	13.52	17.08	23.66	14.53	17.37	25.39	15.81	16.54	27.53
129		2	2	2	21.82	12.29	23.75	17.14	12.9	22.58	23.34	12.08	25.4	23.27	12.45	25.37	20.34	12.51	23.58
130	21	2	2	2	13.6	14.97	21.09	13.58	14.56	21.84	13.68	14.32	23.93	15.57	14.29	25.59	15.62	13.65	23.68
131		2	2	2	16.47	14.2	21.11	18.56	13.47	22.4	16.16	14.65	21.82	14.77	15.13	24.99	16.4	14.72	22.68
132		2	2	2	16.47	13.41	22.54	16.95	12.6	23.38	17.98	12.94	23.33	21.33	11.93	23.7	16.73	13.23	23.21
133		2	2	2	15.9	14.54	23	15.92	13.84	23.76	16.55	13.03	25.66	17.58	12.83	25.71	19.54	13.19	24.38
134		2	2	2	14.23	13.61	21.92	13.92	13.24	22.79	13.55	13.5	22.9	13.88	13.55	22.68	14.96	13.41	22.37
135		2	2	2	17.18	12.81	23.79	17.69	12.54	25.5	17.97	12.98	25.38	18.42	13.33	25.44	19.09	14.01	25.02
136		2	2	2	14.08	14.78	22.69	13.93	14.57	24.6	14.38	15.11	25.29	14.13	14.95	25.27	15.05	14.85	23.65
137	22	2	2	2	13.35	13.34	22.14	13.67	12.91	23.54	14.14	13.28	24.59	15.45	13.04	24.7	15.54	12.52	24.61
138		2	2	2	15.39	14.5	23.45	14.85	14.46	24.04	13.71	15.1	25.9	14.24	14.79	25.83	15.32	14.42	24.38
139	23	2	2	2	13.58	13.25	22.52	13.5	12.47	22.72	12.69	12.47	23.58	15.26	12.83	24.55	14.42	12.58	23.79
140		2	2	2	14.58	14.97	22.96	14.4	13.87	24.58	14.32	13.68	26.74	15.47	13.37	26.84	15.96	13.66	25.86
141		2	2	2	15.24	12.99	20.79	14.63	12.72	22.1	14.56	12.46	23.84	15.82	12.69	24	17.74	12.13	22.41
142	24	2	2	2	14.7	15.2	22.69	15.35	14.81	22.88	15.54	14.8	23.11	14.58	15.24	23.65	14.53	15.23	22.92
143		2	2	2	17.38	11.33	20.66	19.14	12.2	21.85	23.2	13.24	24.23	24.83	13.02	24.31	20.94	13.11	24.12
144		2	2	2	14.34	13.23	21.38	15.07	13.87	21.65	15.09	14.54	21.82	15.97	14.8	21.98	16.11	14.73	20.81
145		2	2	2	17.28	12.31	23.79	16.77	12.62	26.67	15.85	13.92	25.2	18.84	13	25.49	18.1	12.4	25.26
146		2	2	2	15.85	13.8	22.22	15.21	14.92	23.97	15.92	14.74	25.03	16.27	14.18	24.15	17.32	12.74	22.2
147		2	2	2	17.18	13.97	22.37	15.97	14.55	22.88	14.9	15.35	23.97	14.73	14.81	24.01	15.38	14.89	21.78
148		2	2	2	16.14	14.48	23.32	15.55	14.57	23.77	14.61	14.68	24.48	14.64	14.68	25.2	15.24	13.71	23.69
149	25	2	2	2	16.48	14.08	22.19	15.91	14.37	23.15	14.75	14.56	24.2	15.59	14.53	23.33	16.59	15.03	21.98
150		2	2	2	15.18	13.58	21.93	13.8	12.51	23.9	13.97	12.45	25.33	14.6	12.76	26.27	14.43	13.75	25.93

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
151		2	3	2	13.32	14.53	19.99	12.04	14.85	20.13	11.86	14.79	22.12	12.13	14.98	21.59	12.92	14.2	21.49
152		2	3	2	14.43	15.15	24.8	13.63	15.55	23.64	13.42	15.63	24.71	15.04	14.1	25.69	14.92	14.71	22.93
153	26	2	3	2	13.82	13.02	21.78	13.78	12.85	21.43	14.45	12.72	22.5	14.57	13.29	22.88	13.88	12.98	20.83
154		2	3	2	14.85	14.87	23.58	15.57	15.03	24.68	16.5	13.61	24.93	18.74	13.41	26.17	21.09	12.23	24.85
155	27	2	3	2	13.69	15.84	21.44	15.05	16.33	21.72	14.52	15.55	23.68	15.65	16.08	24.61	16.36	15.67	24.67
156		2	3	2	15.45	13.08	23.81	15.44	12.93	24.05	18.63	12.89	24.91	16.12	10.63	24.89	16.6	12.87	23.85
157		2	3	2	17.73	11.52	22.92	16.82	11.43	24.51	19.56	11.71	24.54	20.84	11.93	24.61	18.28	12.69	22.43
158		2	3	2	17.56	12.15	24.57	17.47	12.02	25.96	17.99	12.03	25.55	18.82	12.7	26.67	19.92	12.77	24.61
159		2	3	2	15.79	15.6	22.44	15.09	15.79	24.01	15.04	15.63	25.08	16.91	14.54	24.34	16.96	13.99	21.87
160		2	3	2	15.87	14.44	21.06	15.67	14.13	24.22	16.01	14.39	25.03	17.32	14.46	24.23	16.8	14.28	22.77
161		2	3	2	20.27	12.13	23.65	19.18	11.94	25.69	18.56	11.92	26.78	17.91	13.04	26.21	17.18	13.87	25.95
162		2	3	2	13.47	12.39	22.42	14.86	11.83	23.75	15.9	12.06	24.07	15.99	12.53	23.07	15.21	13.21	20.24
163		2	3	2	15.33	15.71	20.8	14.51	14.7	21.54	15.15	14.3	22.52	16.24	15.31	25.54	14.08	16.34	25.36
164		2	3	2	16.29	14.92	23.43	17.5	13.04	24.2	17.16	12.67	25.4	19.46	12	26.55	19.99	12.57	27.11
165		2	3	2	15.27	14.09	21.91	15.87	12.68	23.58	18.68	11.87	24.09	15.65	13.74	24.48	15.58	13.05	23.98
166		2	3	2	15.82	14.66	20.27	17.45	13.87	22.38	16.76	13.48	23.6	17.78	13.21	23	14.76	13.12	20.59
167	28	2	3	2	16.67	13.62	21.6	17.64	14.52	23.17	17.93	14.5	24.99	18.78	13.57	25.29	18.32	13.38	24.12
168		2	3	2	16.44	17.84	23.87	15.35	16.29	23.52	15.88	15.03	23.86	16.38	14.42	25.4	16.4	14.29	23.95
169	29	2	3	2	13.32	12.13	20.48	13.69	11.61	20.41	16.15	9.89	23.51	16.33	11.38	23.71	17.48	11.14	22.38
170		2	3	2	17.01	14.3	23.22	19.03	13.02	24.24	19.68	13.21	26.04	18.33	14.3	25.26	16.89	14.01	25.61
171		2	3	2	15.53	13.56	22.38	15.37	13.62	23.74	15.59	14.38	24.32	20.53	13.92	24.66	18.33	12.85	24.67
172		2	3	2	13.86	15.27	23.05	13.06	14.9	24.05	11.82	15.6	24.71	11.72	16.59	25.5	11.61	16.9	26.42
173		2	3	2	17.41	13.33	22.24	15.27	12.69	22.11	16.71	11.67	22.98	15.18	12.11	24.38	15.15	13.86	22.95
174		2	3	2	13.78	14.18	20.38	13.79	13.83	21.35	15.98	13.78	22	18.82	11.67	22.48	16.83	11.45	21.15
175		2	3	2	12.21	13.8	21.8	13.79	13.58	23.3	13.73	14.06	23.28	13.33	14.95	23.23	13.66	15.38	22.38
176		2	3	2	13.77	13.78	22.72	14.81	12.62	23.48	15.26	12.49	23.86	14.94	12.43	23.49	15.25	13.1	21.58
177		2	3	2	16.85	13.2	22.93	19.97	12.19	24.53	17.79	13.32	25.26	18.98	13.62	25.97	19.79	13.93	25.88
178		2	3	2	16.88	14.41	24.32	17.06	13.78	24.58	17.14	13.85	24.52	17.84	14.7	24.75	18.23	14.51	24.15
179	30	2	3	2	13.85	14.69	23.01	13.33	14.2	23.53	13.4	15.58	24.1	14.21	15.66	24.32	14.06	15.87	24.68

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
180		3	1	1	15.52	13.35	22.38	16.01	13.24	22.75	14.6	14.15	23.41	14.91	13.81	23.89	15.17	13.38	24.12
181		3	1	1	15.97	16.04	24.53	15.33	15.7	25.37	14.28	16.83	26.77	15.47	17.33	27.25	16.65	16.91	25.09
182		3	1	1	15.75	13.82	23.7	16.014	13.11	24.72	15.25	13.89	25.89	15.53	14.54	26.47	15.76	15.98	23.77
183		3	1	1	18.87	13.98	23.22	18.42	13.18	23.94	17.66	13.7	24.67	18.03	13.53	24.98	19.27	13.41	23.91
184		3	1	1	17.28	13.15	22.49	18.66	13.03	25.5	18.24	11.93	27.22	18.86	11.26	27.7	18.47	10.96	25.93

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
185		3	2	1	17.48	13.8	24.16	17.24	14.2	22.46	17.31	14.16	25.49	17.84	15.31	25.62	18.06	16.58	24.16
186		3	2	1	16.69	10.41	22.42	16.22	10.6	25.09	16.57	11.44	24.68	17.87	12.22	25.87	17.25	13.71	23.59
187		3	2	1	18.93	14.15	24.75	19.2	13.91	25.63	19.18	14.07	25.85	19.34	14.12	26.6	19.97	13.64	25.79
188		3	2	1	19.4	12.09	23.58	17.79	12.27	24.07	17.84	14.8	23.25	20.95	14.35	23.45	21.44	14.18	23.56
189		3	2	1	17.41	15.64	23.4	17.89	16.05	23.54	17.85	16.13	24.28	17.95	15.45	24.81	17.45	15.09	23.67

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
190		3	3	1	17.55	12.09	21.08	17.75	11.72	21.05	16.58	12.35	21.65	16.95	11.95	20.8	17.89	11.62	20.16
191		3	3	1	17.94	13.33	23.64	17.48	12.64	24.56	17.74	12.8	24.98	17.64	13.39	25.72	17.63	13.54	24.94
192		3	3	1	15.31	13.96	21.04	15.11	14.07	22.54	14.54	14.55	23.07	14.82	14.6	23.84	15.62	14.59	23.3
193		3	3	1	17.41	13.43	22.38	17.13	13.73	22.24	16.12	14.26	22.69	16.51	13.98	22.72	17.12	13.48	22.51
194		3	3	1	15.22	13.47	19.77	15.39	12.06	20.98	17.94	11.94	21.64	18.98	11.81	22.27	16.7	12.16	21.61

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
195		3	1	2	14.64	15.47	23.67	14.86	15.43	24.52	15.37	14.93	25.06	16.89	15.03	24.2	17.29	14.36	24.76
196		3	1	2	16.16	12.71	22.07	16.2	12.68	21.05	15.72	13.63	22.57	17.89	13.98	23.88	17.13	13.61	22.64
197		3	1	2	14.17	13.98	20.66	13.72	13.59	22.1	13.82	14.04	24.06	14.65	13.74	24.56	14.94	13.24	23.19
198		3	1	2	14.91	15.13	23.25	14.93	15.32	23.11	15.07	15.69	25.1	16.61	14.97	25.29	17.83	14.06	24.04
199		3	1	2	17.09	13.16	23.13	17.77	13.33	24.01	16.59	13.65	24.97	15.41	13.61	25.76	14.92	13.56	23.42

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
200		3	2	2	13.56	15.32	20.89	13.79	14.26	22.1	13.77	14.08	23.9	15.54	13.55	25.22	15.43	13.68	23.6
201		3	2	2	13.22	13.03	22.14	13.47	12.73	23.31	14.2	13.29	24.57	15.3	13.04	24.45	15.46	12.84	24.54
202		3	2	2	13.47	12.89	22.53	13.43	12.25	21.84	12.67	12.57	22.97	14.87	12.66	23.72	14.42	12.72	23.88
203		3	2	2	14.84	14.58	22.7	15.54	14.56	22.91	15.39	13.93	22.83	14.64	15.01	23.6	14.46	14.8	23.65
204		3	2	2	16.16	14.22	22.38	15.88	14.15	23.16	14.72	14.46	24.28	15.85	14.57	23.26	16.43	14.76	22.14

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
205		3	3	2	13.41	12.46	20.94	13.61	12.59	21.58	14.46	12.63	22.05	14.317	13.17	21.79	13.79	13.05	21.13
206		3	3	2	13.28	16.08	21.23	14.91	16.2	21.56	13.43	15.79	23.76	15.43	15.66	24.04	16.32	15.86	24.53
207		3	3	2	16.18	13.36	21.73	16.56	13.71	22.83	17.47	14.06	24.5	18.47	13.79	22.28	18.55	13.77	23.78
208		3	3	2	13.32	11.72	20.54	13.78	11.3	20.67	15.55	9.97	22.64	16.27	11.53	22.74	17.38	10.58	22.28
209		3	3	2	13.48	14.66	22.89	13.5	14.45	23.78	13.22	15.21	23.85	14.27	15.32	24.36	14.02	15.87	24.69

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
180		4	1	1	15.37	13.27	22.39	15.82	13.33	22.81	14.72	14.07	23.55	15.01	14.04	23.94	15.17	13.24	24.1
181		4	1	1	16.01	16.26	24.53	15.34	15.96	25.37	14.48	16.84	26.7	15.43	17.28	27.23	16.48	16.99	25.15
182		4	1	1	15.66	13.83	23.82	16.13	13.04	24.77	15.2	14.04	25.77	15.64	14.59	26.2	15.87	15.77	23.52
183		4	1	1	18.74	14.05	23.28	18.44	12.94	23.94	17.67	13.63	24.72	17.97	13.42	25	19.18	13.41	23.88
184		4	1	1	17.25	13.18	22.38	18.56	13.04	25.34	18.48	11.89	27.13	18.89	11.52	27.57	18.39	11.05	25.9

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
185		4	2	1	17.62	14	24.16	17.37	14.06	22.53	13.4	13.92	25.37	18.19	15.25	25.78	18.15	16.22	24.25
186		4	2	1	16.79	10.38	22.55	16.38	10.61	25	16.79	11.46	24.93	17.67	12.23	26.14	17.23	13.6	23.71
187		4	2	1	18.79	14.14	23.8	19.08	13.95	25.42	19.29	14.3	25.78	19.3	13.86	26.66	19.95	13.9	26.08
188		4	2	1	19.24	13.08	23.35	17.82	12.03	23.85	18.04	14.63	23.28	21.15	14.25	23.65	21.2	13.94	23.56
189		4	2	1	17.67	15.63	23.46	17.53	16.08	23.26	17.96	16.12	24.32	18.21	15.69	24.84	17.49	15.26	23.69

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
190		4	3	1	17.44	12.2	21.1	17.76	11.86	20.84	20.84	12.42	21.46	16.83	11.82	20.82	17.87	11.66	20.18
191		4	3	1	17.95	13.46	23.55	17.56	12.62	24.31	24.31	13.35	24.9	17.53	13.35	25.75	17.47	13.68	25.01
192		4	3	1	15.22	13.69	21.05	15.14	13.88	22.39	22.39	14.45	23.11	14.88	14.4	24.11	15.75	14.52	25.01
193		4	3	1	17.61	13.62	22.45	16.96	13.78	22.39	22.39	14.27	22.86	16.53	14.11	22.5	17.1	13.4	22.45
194		4	3	1	15.2	13.49	19.64	15.4	11.88	20.89	20.89	11.88	21.72	19.07	11.73	22.11	16.91	12.26	21.62

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
195		4	1	2	14.56	15.58	23.7	14.89	15.27	24.7	15.39	14.96	24.93	16.06	14.85	24.43	17.32	14.41	24.67
196		4	1	2	16.18	12.5	22.09	16.11	12.73	21.09	15.77	13.62	22.62	17.73	13.85	23.83	13.31	13.69	22.61
197		4	1	2	14.26	13.96	20.7	13.8	13.67	21.98	13.7	13.88	23.79	14.58	13.94	24.34	14.98	13.46	23.29
198		4	1	2	15.5	15.27	23.14	14.7	15.27	23.08	15.06	15.48	25.04	16.5	15.01	25.28	17.68	14.21	24.08
199		4	1	2	17.07	13.03	23.2	17.86	13.32	24.21	16.48	13.53	24.9	15.43	13.44	25.86	14.93	13.69	23.23

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
200		4	2	2	13.59	15.31	21.15	13.59	14.33	22.2	13.86	14.21	24.05	15.2	13.86	25.22	15.28	13.6	23.69
201		4	2	2	13.25	13.23	22.18	13.29	12.9	23.19	13.96	13.32	24.58	15.09	13.07	24.52	15.46	12.77	24.33
202		4	2	2	13.45	12.61	22.46	13.53	12.17	22.02	12.85	12.56	23	14.96	12.53	23.46	14.31	12.56	23.69
203		4	2	2	14.69	14.78	22.93	15.63	14.61	22.92	15.5	14.08	23.06	14.7	15.02	23.53	14.5	14.95	23.64
204		4	2	2	16.2	14.17	22.32	16.08	14.17	23.24	14.73	14.29	24.07	15.67	14.52	23.38	16.41	14.89	22.13

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
205		4	3	2	13.38	12.55	20.77	13.65	12.65	21.81	14.38	12.46	22.23	14.21	12.82	21.97	13.82	12.89	21.12
206		4	3	2	13.14	16.03	21.35	15.01	16.14	21.61	14.44	15.86	23.65	15.45	15.78	24.13	16.36	15.7	24.55
207		4	3	2	18.17	13.35	21.81	16.61	13.76	22.93	17.46	14.23	24.55	18.54	13.69	24.44	18.63	13.76	23.74
208		4	3	2	16.89	11.75	20.47	13.68	11.28	20.68	15.29	9.74	22.63	16.32	11.27	22.79	17.46	10.66	22.53
209		4	3	2	17.34	14.6	22.74	13.58	14.19	23.61	13.08	15.14	23.74	14.22	15.47	24.39	14.03	15.97	24.68

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
210		5	1	1	18.17	18.05	26.16	18.91	14.02	26.58	18.38	12.74	28.21	17.9	13.21	31.59	17.56	14.35	30.13
211		5	1	1	16.89	13.46	22.97	16.46	13.5	24.96	15.5	14.49	27.15	13.91	16	28.27	15.91	15.38	28.13
212		5	1	1	17.34	12.94	23.88	16	14.51	26.34	17.32	15.8	27.35	17.57	15.33	26.09	20.03	12.27	28.53
213		5	1	1	15.37	16.47	25.99	16.98	15.87	26.97	18.19	15.23	27.3	19.14	15.65	25.11	18.02	16.52	23.97
214		5	1	1	16.81	13.02	24.05	16.46	13.21	25.29	15.05	14.33	27.66	15.61	15.82	26.52	16.57	16.81	27.52
215		5	1	1	15.29	14.08	24.14	16.47	14.62	28.42	14.49	16.22	30.49	17.32	18.17	29.2	19.03	20.76	25.96
216		5	1	1	15.5	14.4	23.41	15.73	13.21	23.48	15.49	14.14	24.58	17.11	15.51	25.53	16.89	15.06	24.97
217		5	1	1	16.51	15.46	23.77	16.32	14.53	25.62	15.3	17.28	29.11	14	17.81	30.37	19.76	19	27.27
218		5	1	1	16.84	13.29	24.93	15.66	14.01	28	14.98	15.9	29.02	15.19	14.98	28.52	16.37	15.66	27.77
219		5	1	1	18.96	16.39	22.8	20.12	12.54	24.37	20.99	11.84	26.79	21.33	12.93	29.39	19.3	12.76	28.63

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
220		5	2	1	16.95	11.24	23.64	15.65	10.55	24.06	15.44	11.18	25.37	14.53	13.36	26.2	15.5	16.4	27.2
221		5	2	1	15.55	13.51	22.89	15.05	14.82	25.21	15.51	13.87	26.13	15.51	12.96	25.91	15.27	11.8	22.43
222		5	2	1	17.12	14.76	24.18	17.36	12.7	27.92	16.48	14.09	30.07	15.96	17.61	30.26	19.94	15.06	27.64
223		5	2	1	19.01	10.26	22.13	19.01	10.95	23.73	20.31	10.82	24.68	21.09	12.91	24.95	24.39	12.92	25.39
224		5	2	1	15.74	14.1	22.48	15.74	14.13	22.67	16.85	15.13	27.7	19.23	13.89	27.19	20.93	12.86	26.77
225		5	2	1	18.08	12.37	22.21	18.8	12.17	25.65	16.75	13.47	27.77	18.61	15.75	27.19	19.4	15.75	23.73
226		5	2	1	15.19	18.4	27.58	14.6	14.62	25.96	13.93	15.14	26.74	14.56	14.56	26.53	15.2	14.13	28.26
227		5	2	1	17.82	14.72	23.53	16.29	15.61	23.76	15.4	16.27	26.85	11.45	16.73	25.07	20.07	17.83	24.41
228		5	2	1	17.2	11.83	25.2	17	11.81	28.46	15.75	12.65	28.86	21.01	12.85	29.01	22.17	13.08	24.87
229		5	2	1	17.89	13.21	23.32	17.62	12.22	25.42	18.7	12.7	28.75	21.56	12.43	26.96	23.33	12.96	24.45

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
230		5	3	1	17.51	15.77	24.76	20.54	16	27.28	21.5	14.88	28.77	20.77	16.25	23.76	21.04	15.75	23.19
231		5	3	1	18.45	13.41	23.5	16.22	13.26	25.09	15.86	14.81	28.61	20.72	13.99	25.8	21.3	14.27	24.02
232		5	3	1	16.64	13.48	24.05	16.47	13.16	25.19	13.36	13.35	24.44	16.98	14.87	24.98	16.59	14.11	23.46
233		5	3	1	18.75	11.38	22.49	17.75	12.13	23.58	18.97	13.02	24.01	18.87	14	24.4	20.85	13.63	22.97
234		5	3	1	16.89	14.5	23.65	16.77	14.64	24.88	17.63	13.37	26.12	20.26	13.4	27.63	22	12.25	25.2
235		5	3	1	18.38	12.76	22.81	18.88	12.27	25.64	15.62	13.5	26.82	16.88	18.93	25.75	19	17.17	23.04
236		5	3	1	21.46	10.66	20.68	22.67	10.44	21.97	23.32	10.15	23.92	22.03	10.45	22.35	22.05	12.01	22.2

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
237		5	1	2	14.68	12.46	21.4	15.19	12.32	22.06	14.73	12.63	24.46	14.53	13.17	23.04	13.95	12.84	23.08
238		5	1	2	16.48	12.67	22.6	16.48	13.06	26.05	14.61	14.04	26.86	15.65	14.91	28.48	17.22	12.29	27.76
239		5	1	2	13.25	16.16	21.69	13.5	15.67	22.89	13.01	15.66	25.3	12.53	15.66	26.27	14.7	14.77	22.97
240		5	1	2	14.77	12.38	21.87	15.61	12.38	23.22	14.71	12.94	24.32	12.57	13.56	26.56	11.33	13.84	24.81
241		5	1	2	13.39	12.74	22.83	14.62	11.95	24.54	15.07	11.32	25.45	18.57	11.92	25.27	15.14	13.16	26.28
242		5	1	2	12.13	15.85	19.43	14.56	14.22	19.17	15.21	13.1	21.92	13.78	13.4	22.02	14.24	13.48	21.25
243		5	1	2	14.54	12.66	22.68	15.73	12.68	25.69	14.55	15.04	29.98	14.17	16.27	29.31	13.98	14.64	29.43
244		5	1	2	11.8	12.02	23.6	12.27	13.71	25.44	9.94	13.66	24.08	12.97	13.41	24.14	11.56	13.87	21.99
245		5	1	2	14.95	14.5	23.84	16.17	15.96	25.91	16.79	14.09	24.67	18.65	15.8	25.54	19.91	12.64	22.33

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
246		5	2	2	14.53	11.5	24.24	14.53	11.91	25.44	16.75	11.91	26.44	19.39	10.7	24.82	19.7	10.5	23.61
247		5	2	2	14.16	16.91	24.51	17.25	16.75	25.27	17.52	15.51	25.53	20.01	16	26.82	20.51	13.79	25.75
248		5	2	2	14.07	13.99	21.73	14.83	13.21	22.27	13.35	14.08	23.3	13.71	16.64	23.61	12.43	18.73	23.29
249		5	2	2	8.11	12.37	23.32	21.24	14.23	24.27	19.11	14.3	29.41	20.75	15.53	25.66	21.42	13.66	27.27
250		5	2	2	15.55	13.8	24.12	16.25	13.28	27.79	13.45	14.51	27.43	16.96	15.55	25.86	18.52	15.65	24.04
251		5	2	2	18.02	11.55	23.1	18.62	10.77	24.28	17.43	11.36	25.84	17.03	11.94	26.07	17.23	11.95	27.25
252		5	2	2	14.22	13.65	25.19	14.27	13.67	24.66	14.06	13.89	27.14	12.88	14.65	26.36	14.06	13.49	24.24
253		5	2	2	13.8	11.98	23.92	14.22	11.68	24.93	14.42	12.6	26.59	12.6	14.19	26.56	13.74	15.58	29.53
254		5	2	2	11.5	11.46	23.25	15.19	11.85	26.94	21.09	11.79	29.28	21.87	17.78	28.71	22.92	12.09	26.1
255		5	2	2	14.39	15.51	22.43	13.39	15.63	22.68	16.75	15.73	22.62	16.89	15.89	23.39	18.26	14.79	22.89

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
256		5	3	2	17.36	11.03	22.47	15.15	12.25	25.95	21.25	12.05	25.44	21.47	17.58	24.51	28.18	13.48	20.93
257		5	3	2	17.1	12.93	22.52	16.45	12.54	25.65	17.23	14.94	26.24	19.58	18.21	27.23	20.95	24.08	25.26
258		5	3	2	18.01	11.88	22.28	17.64	12.02	24.57	16.75	12.27	26.24	18.31	12.51	27.04	18.69	12.91	28.23
259		5	3	2	21.18	13.52	27.76	20.05	14.43	28.22	20.5	14.41	27.23	22.95	15.14	26.67	22.57	13.58	25.49
260		5	3	2	15.4	12.62	21.6	16.41	12.49	24.61	12.84	13.47	24.38	16.32	13.49	26.82	15.18	13.5	24.62
261		5	3	2	18.05	13.72	20.54	14.98	14.06	22.55	14.96	13.88	24.54	16.22	13.53	23.79	16.41	12.45	22.16
262		5	3	2	17.07	11.41	23.62	16.7	10.92	26.18	15.89	11.94	30.85	17.84	14.84	27.56	20.24	16.98	27.61
263		5	3	2	14.58	16.18	22.59	14.06	12.91	22.36	14.05	13.92	24.46	15.28	13.58	24.21	15.91	16.09	25.46
264		5	3	2	17	13.75	21.87	19.38	13.76	23.01	19.63	16.88	25.26	22.37	16.08	25.81	22.78	14.28	23.29

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
210		6	1	1	18.05	18.03	26.15	18.81	14.02	26.48	18.38	12.58	28.68	17.89	13.22	31.58	17.73	14.06	30.3
211		6	1	1	16.64	13.58	22.92	16.66	13.51	25.02	15.68	14.71	27.01	13.81	16.26	28.42	15.75	15.37	28.25
212		6	1	1	17.19	13.16	23.86	16.26	14.73	26.34	17.03	16	27.56	17.37	15.37	25.84	20.03	12.01	28.5
213		6	1	1	15.07	16.43	26.03	16.85	15.7	27.01	18.25	15.18	27.3	19.37	15.41	25.33	18.03	16.29	24.26
214		6	1	1	17.09	13.19	24.2	16.29	13.05	25.29	15.2	14.55	27.84	15.55	15.9	26.75	16.57	16.57	27.5
215		6	1	1	15.26	14.1	24.29	16.36	14.57	28.68	14.49	16.02	30.28	17.31	18.17	29.41	18.82	20.54	25.99
216		6	1	1	15.74	14.43	23.43	15.74	13.48	23.41	15.27	14.14	24.58	17.34	15.74	25.24	16.71	15.06	24.98
217		6	1	1	16.52	14.29	23.8	16.1	14.36	25.35	15.57	17.32	29.11	13.77	17.76	30.37	19.76	19.25	27.26
218		6	1	1	16.84	13.54	25.18	15.43	14.24	27.76	14.96	15.7	29.02	15.18	15.19	28.27	16.13	15.66	28.01
219		6	1	1	18.92	16.4	22.95	20.37	12.55	24.39	20.79	11.77	26.75	21.11	12.58	29.38	19.35	12.51	28.59

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
220		6	2	1	17.03	11.32	23.46	15.7	10.33	24.14	15.38	11.18	25.1	14.62	13.41	26.37	15.73	16.42	27.18
221		6	2	1	15.77	13.54	22.9	15.05	14.81	25.21	15.26	13.69	26.13	15.52	12.77	26.13	15.29	11.8	22.24
222		6	2	1	17.11	14.99	23.93	17.46	12.67	27.99	16.48	14.1	30.29	15.72	17.57	30.27	19.68	15.08	27.86
223		6	2	1	19.21	10.26	21.96	19.17	10.95	23.87	20.3	11	24.68	20.9	12.98	24.91	24.22	12.93	25.53
224		6	2	1	15.74	14.31	22.69	15.52	14.1	22.67	16.79	14.96	27.63	19.4	13.89	27.2	20.88	12.86	26.78
225		6	2	1	18.25	12.17	22.41	18.81	11.99	25.67	16.77	13.48	27.72	18.43	15.75	27.14	19.17	15.94	23.91
226		6	2	1	14.99	18.26	27.69	14.46	14.73	26.03	14.14	15.28	26.75	14.41	14.56	26.67	15.14	13.98	28.48
227		6	2	1	17.82	14.45	23.76	16.05	15.65	23.75	15.42	16.23	26.85	11.43	16.97	25.07	20.33	17.87	24.41
228		6	2	1	17.2	11.82	25.38	17.21	12.02	28.64	15.58	12.45	28.7	21.01	12.64	28.8	22.38	13.06	24.87
229		6	2	1	17.89	13.21	23.34	17.86	12.2	25.66	18.92	12.7	28.78	21.8	12.44	26.97	23.33	12.95	24.35

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
230		6	3	1	17.53	15.76	24.51	20.51	15.77	27.56	21.25	14.88	28.78	20.76	16.26	23.56	21	15.75	23.23
231		6	3	1	18.36	13.41	23.32	16.23	13.12	25.19	15.91	15.02	28.79	20.59	12.93	25.96	21.53	14.04	23.85
232		6	3	1	16.62	13.46	24.24	16.44	12.98	24.84	13.54	13.16	24.44	16.79	14.86	24.98	16.78	14.12	23.46
233		6	3	1	18.91	11.56	22.48	17.67	12.13	23.65	18.78	13.17	23.97	18.58	14.14	24.34	20.79	13.42	22.82
234		6	3	1	16.76	14.25	23.76	16.69	14.66	24.88	17.63	13.5	26.12	20.09	13.39	27.88	22.01	12.25	25.34
235		6	3	1	18.38	12.77	23.05	19	12.38	25.64	15.75	13.75	26.67	16.63	18.89	25.88	18.91	17.18	23.14
236		6	3	1	21.41	10.63	20.76	22.75	10.29	21.99	23.38	10.08	24.19	22.22	10.44	22.23	22.04	12	22.12

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
237		6	1	2	15.43	12.31	21.42	15	12.5	22.05	14.78	12.52	24.66	14.48	12.99	22.83	14.27	12.81	22.9
238		6	1	2	16.5	12.51	22.59	16.62	12.87	25.9	14.78	14.12	27.09	15.4	15.18	28.65	17.47	12.25	27.66
239		6	1	2	13.25	15.91	21.69	13.5	15.49	23.13	13.01	15.66	25.55	12.53	15.66	26.27	14.46	14.59	22.91
240		6	1	2	14.73	12.35	21.89	15.41	12.38	23.02	14.9	13.08	24.3	12.79	13.56	26.34	11.22	14.02	24.84
241		6	1	2	13.53	12.55	22.93	14.55	11.75	24.45	15.3	11.1	25.65	18.77	12.15	25.46	14.94	13.16	26.08
242		6	1	2	12.17	16.03	19.48	14.47	14.39	19.28	15.4	13.19	22.16	13.73	13.19	22.13	14.19	13.73	21.25
243		6	1	2	14.55	12.92	22.88	15.68	12.65	25.68	14.56	14.85	29.76	14.15	16.28	29.35	14.12	14.7	29.2
244		6	1	2	11.81	12.27	23.82	12.02	13.48	25.2	10.18	13.64	24.3	12.79	13.41	24.1	11.57	13.88	21.98
245		6	1	2	14.93	14.3	23.84	16.37	15.8	26.11	16.79	13.91	24.67	18.87	15.78	25.33	19.71	12.86	22.21

ID	IdIn	M	Age	Sex	w11	w12	w13	w21	w22	w23	w31	w32	w33	w41	w42	w43	w51	w52	w53
246		6	2	2	14.74	11.71	24.44	14.53	11.91	25.25	16.77	11.91	26.44	19.63	11.9	24.62	19.79	10.7	23.81
247		6	2	2	14.26	17.02	24.51	17.5	16.75	25.28	17.76	15.5	25.77	20.25	15.78	27.02	20.6	13.77	25.5
248		6	2	2	14.06	13.81	21.86	14.83	13.36	22.24	13.39	13.87	23.29	13.69	16.67	23.42	12.3	18.99	23.48
249		6	2	2	7.97	12.55	23.17	21.02	14.05	24.41	19.11	14.15	29.5	20.87	15.28	25.75	21.28	13.62	27.27
250		6	2	2	15.55	13.98	24.12	16.28	13.1	27.78	13.63	14.35	27.6	16.77	15.57	25.86	18.34	15.45	24.16
251		6	2	2	18.22	11.36	23.31	18.64	10.59	24.28	17.64	11.36	25.84	17.23	11.75	26.06	17.23	12.14	27.23
252		6	2	2	14.42	13.48	25.39	14.42	13.84	24.6	13.86	13.89	27.17	12.69	14.32	26.36	14.04	13.3	24.45
253		6	2	2	14.01	11.95	23.94	14.34	11.73	25.16	14.66	12.61	26.83	12.82	14.19	26.58	13.99	15.58	29.3
254		6	2	2	11.69	11.6	23.26	15.17	11.76	27.04	21.01	11.75	29.26	21.82	17.54	28.53	23.16	12.17	26.02
255		6	2	2	14.53	15.39	22.3	13.38	15.63	22.92	16.88	15.38	22.63	16.76	16.05	23.27	18.17	14.57	22.88
ID	**IdIn**	**M**	**Age**	**Sex**	**w11**	**w12**	**w13**	**w21**	**w22**	**w23**	**w31**	**w32**	**w33**	**w41**	**w42**	**w43**	**w51**	**w52**	**w53**
256		6	3	2	17.18	11.23	22.47	15.16	12.25	26.14	21.04	12.05	25.37	21.66	17.36	24.74	28.18	13.48	21.11
257		6	3	2	17.43	13.12	22.52	16.45	12.35	25.46	17.42	14.77	26.04	19.38	18.23	27.26	20.95	24.08	25.26
258		6	3	2	17.81	12.01	22.07	17.48	11.98	24.51	16.84	12.19	26.47	18.22	12.38	27.25	18.51	12.87	28.18
259		6	3	2	21.37	13.31	27.52	19.94	14.21	28.23	20.5	14.41	27.46	22.74	15.34	26.72	22.4	13.55	25.74
260		6	3	2	15.65	12.85	21.6	17.11	12.62	24.38	13.05	13.27	24.6	16.53	13.3	26.75	15.19	13.48	24.39
261		6	3	2	18.02	13.88	20.55	14.78	14.25	22.73	14.78	13.69	24.4	16.41	13.51	23.62	16.4	12.25	22.16
262		6	3	2	17.27	11.37	23.8	16.67	10.92	26.15	15.77	12.05	30.76	17.95	14.67	27.67	20.21	17.04	27.6
263		6	3	2	14.45	16.12	22.59	14.2	12.92	22.45	13.94	13.78	24.55	15.44	13.65	24.2	15.99	16.11	25.25
264		6	3	2	17.25	13.88	21.87	19.38	13.65	23.26	19.51	16.63	25.13	22.4	16.32	25.67	22.64	14.16	23.31

9.3.2 Presence of Ossification of posterior longitudinal ligament and osteophytes in the cervical spinal canal

Dataset Key: Presence of osteophytes graded on a scale of 0 to 3

- OL – Ossification of the posterior longitudinal ligament
- PVBS – Posterior vertebral body, superior aspect
- PVBI – Posterior vertebral body, inferior aspect

		MALES 30-45															
ID	**Sex**	**Age**	**C3**			**C4**			**C5**			**C6**			**C7**		
			OL	**PVBS**	**PVBI**	**PL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**
1	m	30	1	0	2	1	1	0	0	1	1	1	0	1	0	0	0
2	m	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	m	31	1	1	1	1	1	2	0	1	0	0	0	0	0	0	0
4	m	32	1	0	1	1	1	2	0	1	0	0	0	0	0	0	0
5	m	34	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
6	m	35	1	0	1	1	0	1	1	0	1	1	1	1	1	0	0
7	m	35	1	0	0	1	0	1	0	1	0	0	0	1	0	1	0
8	m	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	m	37	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0
10	m	39	0	2	2	0	2	2	0	2	2	0	0	1	0	0	0
11	m	40	1	1	1	1	2	1	0	1	0	0	1	1	0	0	0
12	m	40	0	0	2	0	2	2	0	3	3	0	2	0	0	0	0
13	m	40	1	0	0	1	0	0	0	0	0	1	1	1	0	0	0
14	m	40	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
15	m	40	1	1	0	0	2	2	0	2	2	0	1	0	0	0	0
16	m	41	1	0	0	1	1	1	1	0	1	0	1	0	0	0	0
17	m	42	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0
18	m	43	0	1	1	0	1	1	0	1	1	0	0	0	0	0	0
19	m	44	1	1	1	1	0	0	0	0	1	0	1	1	0	1	0
20	m	45	1	0	1	0	1	1	0	1	1	0	1	1	0	0	1

		MALES 46-60															
ID	**Sex**	**Age**	**C3**			**C4**			**C5**			**C6**			**C7**		
			PL	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**
1	m	46	0	0	0	0	1	0	0	0	1	0	2	0	0	1	0
2	m	48	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
3	m	48	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0
4	m	49	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0
5	m	50	1	1	1	1	2	1	0	1	1	0	2	1	0	2	0
6	m	50	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
7	m	50	1	1	1	0	1	2	0	2	2	0	1	0	0	0	0
8	m	52	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
9	m	52	1	0	1	0	1	1	0	0	1	0	1	0	0	0	1
10	m	53	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
11	m	53	1	1	1	1	2	1	0	2	1	0	1	0	0	0	0
12	m	54	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
13	m	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
14	m	55	1	1	0	1	0	1	1	1	1	1	0	1	0	0	0
15	m	57	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0
16	m	58	1	1	1	1	1	1	0	1	1	0	1	0	0	0	0
17	m	60	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1
18	m	60	1	1	2	0	2	2	0	1	1	0	2	1	0	1	1
19	m	60	1	2	2	1	1	2	0	1	1	0	1	1	0	0	1
20	m	60	0	1	1	0	2	1	0	1	1	0	1	0	0	1	0

		MALES 61-75															
ID	**Sex**	**Age**	**C3**			**C4**			**C5**			**C6**			**C7**		
			OL	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**PL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**
1	m	61	1	1	1	1	1	1	0	0	1	1	1	0	1	0	1
2	m	62	1	1	1	0	2	1	0	2	0	0	0	1	0	1	1
3	m	64	0	1	0	0	1	1	0	1	1	0	0	0	0	0	1
4	m	64	1	1	0	1	1	1	0	2	1	0	0	1	0	0	0
5	m	65	0	1	1	0	2	1	0	1	1	0	2	1	0	1	1
6	m	65	0	1	1	0	1	1	0	1	0	0	0	1	0	0	1
7	m	66	1	1	0	0	0	1	0	2	1	0	2	0	0	0	1
8	m	68	1	0	1	0	1	1	0	1	0	0	0	1	0	0	1
9	m	70	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
10	m	70	1	1	1	1	1	2	0	2	2	0	2	2	0	2	1
11	m	70	0	1	2	0	2	2	0	2	1	0	2	1	0	2	1
12	m	70	1	2	1	1	2	1	0	1	2	0	1	1	0	2	1
13	m	70	1	1	1	1	1	1	1	1	1	0	2	1	0	2	1
14	m	71	1	1	1	1	2	1	0	1	1	0	2	2	0	1	1
15	m	72	0	1	1	0	1	1	0	1	1	0	2	1	0	1	1
16	m	72	0	1	1	0	1	1	0	2	1	0	2	1	0	1	1
17	m	74	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1
18	m	75	1	1	1	0	2	1	0	1	1	0	1	1	0	1	1
19	m	75	1	0	1	1	1	0	1	1	1	0	1	1	0	0	1
20	m	75	1	1	1	0	2	1	1	1	1	0	2	1	0	1	0

FEMALES 30-45																	
ID	Sex	Age	C3			C4			C5			C6			C7		
			OL	PVBS	PVBI	OL	PVBS	PVBI	OL	PVBS	PVBI	OL	PVBS	PVBI	OL	PVBS	PVBI
1	f	30	1	1	1	1	0	0	1	1	1	0	1	0	0	0	1
2	f	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	f	30	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
4	f	32	1	0	1	0	0	1	0	1	1	0	1	1	0	0	1
5	f	33	1	1	1	0	2	1	0	1	1	0	0	1	0	0	1
6	f	35	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0
7	f	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	f	37	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
9	f	38	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
10	f	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	f	40	0	1	0	0	1	0	0	1	0	0	1	0	0	0	1
12	f	42	0	0	1	0	2	1	0	1	1	0	1	0	0	0	0
13	f	42	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
14	f	44	1	1	0	0	1	0	1	1	1	1	1	1	1	1	0
15	f	44	1	1	0	1	1	1	0	1	0	0	0	0	0	0	0
16	f	45	1	1	2	0	2	2	0	1	1	0	0	0	0	0	0
17	f	45	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1

	FEMALES 45-60																
ID	**Sex**	**Age**	**C3**			**C4**			**C5**			**C6**			**C7**		
			OL	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**	**OL**	**PVBS**	**PVBI**
1	f	46	0	1	1	1	1	0	0	1	1	0	1	1	0	0	0
2	f	47	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
3	f	48	1	1	0	1	2	1	1	1	1	1	1	1	0	0	1
4	f	48	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1
5	f	49	1	1	1	1	1	1	1	1	1	0	1	0	0	0	1
6	f	49	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0
7	f	50	0	1	1	0	2	1	0	2	1	0	2	1	0	2	1
8	f	50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
9	f	50	0	1	2	0	1	1	0	1	2	0	2	1	0	0	1
10	f	50	0	1	1	1	2	2	0	2	1	0	1	0	0	0	1
11	f	52	1	0	1	1	1	1	0	0	0	0	0	1	0	0	0
12	f	54	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1
13	f	55	1	1	1	1	1	1	0	1	0	0	1	0	0	0	1
14	f	55	0	2	2	0	2	2	0	3	1	0	2	1	0	1	1
15	f	55	1	1	1	1	1	1	0	1	1	0	1	1	0	0	1
16	f	56	1	1	1	0	2	1	0	1	1	0	1	1	0	1	0
17	f	57	0	0	0	0	1	0	0	1	0	0	1	0	0	0	1
18	f	59	0	2	2	0	2	1	0	1	2	0	1	1	0	1	1
19	f	60	0	1	1	0	1	0	0	1	1	0	1	0	0	0	0
20	f	60	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1

FEMALES 61-75																	
ID	Sex	Age	C3			C4			C5			C6			C7		
			OL	PVBS	PVBI	OL	PVBS	PVBI	OL	PVBS	PVBI	OL	PVBS	PVBI	OL	PVBS	PVBI
1	f	63	1	1	2	1	2	1	1	1	1	1	2	1	0	1	1
2	f	64	1	2	1	1	2	1	0	1	1	0	2	1	0	1	0
3	f	65	1	1	2	1	2	1	1	1	1	1	2	2	1	2	1
4	f	65	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0
5	f	65	1	1	1	1	1	1	1	1	1	1	2	2	1	0	0
6	f	70	1	1	2	1	2	1	0	1	2	0	2	2	1	2	1
7	f	70	0	1	1	0	1	0	0	1	1	0	1	0	0	1	1
8	f	70	0	1	1	0	1	2	0	1	2	0	1	1	0	1	1
9	f	71	1	1	2	1	1	2	1	2	2	1	1	1	0	1	1
10	f	75	1	1	1	1	1	1	0	1	1	0	1	0	0	0	0