SOUTH AFRICAN ANTHROPOMETRIC DIMENSIONS FOR THE DESIGN OF AN ERGONOMIC OFFICE CHAIR

BY

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ABSTRACT

Office chairs are becoming a modern status symbol in the workplace. Many individuals are seated on office chairs for most of the working day. As a result of using poorly designed chairs injury and discomfort are frequently experienced, most particularly lower back pain. Correct design of chairs is imperative, and must be user-centered.

The aim of this investigation has been to gather anthropometric dimensions characteristic of the South African population, as this information has not been widely assimilated to date. Once collated, this information could be used in the design of an ergonomically correct office chair, suitable for the unique characteristics of the South African working population. Anthropometric dimensions were collected from 683 South Africans (comprising 448 South African females and 235 South African males) from pre-selected companies in major centres in South Africa (Johannesburg, Pietermaritzburg, Durban, East London, Grahamstown, Port Elizabeth and Cape Town). Measurements included participants' personal information (age, sex, home language and ethnic group), basic anthropometric measures (stature, shoulder height, mass, and waist and hip circumference) as well as specific measures of fit of the individual to the specially designed, adjustable chair.

Of the 448 females, 317 were Black females, 77 were White females, 35 were Coloured females and 19 were Indian/Asian females. Of the 235 males, 112 were Black males, 79 were White males, 26 were Coloured males and 18 were Indian/Asian males. Office chair dimensions for each ethnic group were represented and differences were noted. A comparison between a current office chair's dimensions and the South African sample office chair's dimensions indicated modifications that would need to be constructed to suit the South African sample. The conventional office chair is still the most widely accepted office chair due to its stability and support structures that maintain the correct sitting posture of the user. An ergonomic office chair needs to incorporate anthropometric dimensions worldwide.

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CHAPTER I

INTRODUCTION

BACKGROUND TO THE STUDY

Chairs are a feature of global society. Individuals spend major portions of the working day seated and it is well known that poor chair design contributes to the development of musculoskeletal disorders (MSDs) and lower back pain (LBP) (Robertson *et al*., 2009). To reduce the contribution of the chair to MSDs, the specific anthropometric dimensions of the population must inform the design. South Africans display many unique anthropometric features which have, to date, not been considered in the design of office chairs (Puoane *et al.,* 2002).

Each feature of an office chair plays a specific role or support function in optimising comfort of the user. However, if the feature does not suit the user, discomfort and injuries will occur. The backrest is essential in supporting the upper body to allow for the muscles to relax periodically, reducing fatiguing of muscles (Kroemer and Grandjean, 1997). The lumbar support needs to maintain the lumbar curve while seated as the pelvic girdle rotates and flattens the lumbar curve and this puts added pressure on ligaments (Kroemer 2009). Seat height should be adjusted according to the popliteal height of the user to reduce pressure on the underside of the thighs (Chengalur *et al*., 2004). If the seat height is positioned too high, this will result in pressure on the underside of the thighs. The positioning of the screen too high or too low will influence the sitting posture. The neck and head would either be flexed or extended and this would result in neck, head and shoulder muscle discomfort (Pheasant and Haslegrave, 2006).

Kroemer and Grandjean (1997) state a number of different seating postures that office workers maintained during a working day. The different postures were alternated throughout the day to reduce discomfort that occurred in certain areas of the body due to long sitting durations. Furthermore, discomfort resulted due to

incorrect adjustments to the office environment and office chair. Kroemer and Grandjean (1997) also indicated musculoskeletal troubles during a sedentary office job. Back pain, particularly lower back pain, was the most common incident reported. Other bodily aches occurred in the neck, shoulders, knees, feet and thighs.

Back pain is a major health problem as it affects a large number of individuals each year (Maniadakis and Gray, 2000). It causes disabilities and economic loss each year and in recent years it has increased rapidly. Maniadakis and Gray (2000) stated that in 1994 to 1995, 116 million productive days were lost due to work-related back pain. The main concern for companies is the production losses due to inefficiency at work, an estimated loss of £3440 million, which could be as high as £9090 million. Back pain represents a greater economic burden than other MSD-related diseases in the United Kingdom (Maniadakis and Gray, 2000).

The South African population was selected as the dimensions of this population have not yet been considered in office chair design. Currently office chairs are manufactured according to the measurements of North American and European populations, first world countries (Gurr et al., 1998). The South African population has unique anthropometric characteristics as it has a diverse culture and a number of ethnic groups (Puoane et al., 2002). The South African population is made up of 79.4% Black, 9.2% White, 8.8% Coloured and 2.6% Indian/Asian and each ethnic group has unique anthropometric characteristics (Lehohla, 2010). The increasing rates of overweightness and obesity due to sedentary lifestyles and cultural beliefs are also a concern in the South Africa population. These cultural beliefs include the idea that the larger the individual, the less likely the individual is to be affected by the Aids Virus, and the more likely that females could bear a number of children (Jung, 2005). The increase in rates of overweightness and obesity may, in turn, influence the design of office chairs in the future and must be considered when collating anthropometric population dimensions.

This study aims to obtain anthropometric dimensions of the South African population in order to design an ergonomic office chair to suit the South African population and each ethnic group (Black, White, Coloured and Indian/Asian) specifically. Designing

an office chair with the anthropometric dimensions of the South African population could result in a more comfortable office chair.

STATEMENT OF THE PROBLEM

Dimensions for an office chair to fit the unique South African population have not yet been established. This study aims to collate a representative set of anthropometric dimensions to inform future chair design in an ergonomic and user-focused manner.

RESEARCH HYPOTHESIS

It is hypothesised that correct chair dimensions to suit the South African user population will differ from the dimensions of currently available office chairs. It is further hypothesised that dimensions for South African males will differ to those applicable to South African females, and that, within these sex groups, ethnic diversity will also result in differences in ideal dimensions for chair design.

STATISTICAL HYPOTHESES

The null hypothesis (H_O) states that the dimensions of the current chair variables are the same as the dimensions of the chair variables obtained from the South African sample and from each ethnic group. The alternate hypothesis (H_A) states that the dimensions of the current chair variables differ from the dimensions of the chair variables obtained from the South African sample and from each ethnic group.

1. H_O: (Variables) Current chairs = (Variables) South African anthropometric dimensions
   H_A: (Variables) Current chairs ≠ (Variables) South African anthropometric dimensions

2. Ho: (Variables) Current chairs = (Variables) South African Female Anthropometry

H_A: (Variables) Current chairs ≠ (Variables) South African Female Anthropometry

Ho: (Variables) Current chairs = (Variables) South African Male Anthropometry

H_A: (Variables) Current chairs ≠ (Variables) South African Male Anthropometry

3. Ho: (Variables) Current chairs = (Variables) South African Black Female Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African Black Female Anthropometry

   Ho: (Variables) Current chairs = (Variables) South African White Female Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African White Female Anthropometry

   Ho: (Variables) Current chairs = (Variables) South African Coloured Female Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African Coloured Female Anthropometry

   Ho: (Variables) Current chairs = (Variables) South African Indian/Asian Female Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African Indian/Asian Female Anthropometry

   Ho: (Variables) Current chairs = (Variables) South African Black Male Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African Black Male Anthropometry

   Ho: (Variables) Current chairs = (Variables) South African White Male Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African White Male Anthropometry

   Ho: (Variables) Current chairs = (Variables) South African Coloured Male Anthropometry

   H_A: (Variables) Current chairs ≠ (Variables) South African Coloured Male Anthropometry

Ho: (Variables) Current chairs = (Variables) South African Indian/Asian Male Anthropometry

H_A: (Variables) Current chairs ≠ (Variables) South African Indian/Asian Male Anthropometry

Variables = seat height, seat depth anterior and posterior, seat width, backrest height, backrest width, lumbar support height, edge of lumbar support height, armrest height, armrest length, backrest point, lumbar support point and cushion depth.

DELIMITATIONS

This study was delimited to South Africans between the ages of 18 and 65. A total of 683 male and female South Africans of different ethnic groups (Black, White, Coloured and Indian/Asian) in South Africa participated in the study. The study was delimited to South Africans currently in employment and the participants were delimited to those without physical, deformity or incapability.

LIMITATIONS

Data collection occurred in Johannesburg, Pietermaritzburg, Durban, East London, Grahamstown, Uitenhage and Cape Town. Therefore, many towns and cities in South African were not represented as data collection did not occur in the north-western regions, due to the time constraints of a Master's thesis. Another limitation is that the sample size was relatively small compared to the South African population size. Limitations could also have occurred in the data collection with the equipment used to measure the anthropometric dimensions. Another limitation could be the construction of the demo chair, as the structure of the chair was taken from the original office chair model and modified according to the South African sample chair dimensions. This study also did not have a test-retest session in order to ensure no errors were made during the anthropometric measurements. However, retesting the participants would result in a longer test session and management might have found this problematic. There also could have been other anthropometric and chair

measurements that could have been implemented in this study that previous studies included.

CHAPTER II

REVIEW OF LITERATURE

DESIGN OF AN OFFICE CHAIR

Chair design is important as it is required to maintain a good sitting posture for an individual. A number of factors need to be considered when designing a chair, as each component of the chair has important functions (Jindo *et al*., 1995). For example, the lumbar support and the backrest supports stabilise the lumbar spine and upper body and therefore decrease the muscle activity of the muscles supporting the posture (Groenesteijn *et al*., 2009). The seat height of the chair is adjustable to each user's leg height and therefore allows blood flow to the lower extremities. The angle of the seat pan and backrest will also influence discomfort ratings due to shear forces within the spinal column (Goossens and Snijders, 1995). Adjustable chairs are stated to be more ergonomically as they adjust to the user's anthropometry (Jung, 2005). Chair design is an on-going process to design according to the anthropometry of the population. The office chair needs to incorporate these dimensions in order to provide comfort for the users.

Many different types of alternative chair designs have been developed, such as the balance chair, kneeling chair and the saddle chair, and they all have specific components and support structures (Bujaryn, 1994). There have been further studies done on seat pan appearance, such as whether it should be high or low, cushioned or hard, tilted (Goossens and Snijders, 1995), contoured or flattened, in order to design the most appropriate chair. However, no one design has been found to be universally accepted (Kroemer, 2009). All these features of the different types of office chairs have their pros and cons, such as lack of stability, support and pressure on non-supportive body structures.

CHAIR CHARACTERISTICS

POSTURE CONTROL

The purpose of an office chair is to stabilise and support the posture of the individual (Pheasant and Haslegrave, 2006). The same authors stated that a chair has to maintain comfort over a long period of time; it has to be physiologically satisfactory and it must be appropriate for the task and activity that the individual is required to perform while seated on it. Many aspects need to be taken into account before designing a chair, namely the seat characteristics, user characteristics and task characteristics (Pheasant and Haslegrave, 2006).

Seat characteristics include aspects such as seat dimensions, angles, profile, stability and upholstery. The seat characteristics provide support for the trunk, shoulders, lower body and head. Without this support, the individual's musculoskeletal system will be supporting the body and this will eventually lead to musculoskeletal disorders. If the seat profile does not match the user's body type, added pressure will be placed on soft tissue which is not designed for weight bearing (Kroemer, 2009). Form and softness are also important aspects to consider when designing a chair, as the seat supports and applies pressure to joints and soft tissues (Vink, 2005). According to Kroemer (2009), a seat pan should have rounded front edges and should be cushioned, thus avoiding pressure behind the leg. Goossens and Snijders (1995) found that the inclination of seat and backrest are of the most important design criteria for chairs. With a seat and backrest inclination of 90 to 95 degrees there was only slight shear forces, resulting in reduced pressure within the spinal column. With a greater inclination angle or tilted backrest and seat pan, the pressure on the discs is the lowest. The pressure at an upright, 90 degree seated angle was 1.6 bars and when the individual was seated in the most comfortable posture, with a greater inclination angle, the pressure on the discs was 0.5 bars (Zenk *et al.*, 2012).

According to Bridger (2003), the key features of chair design include the following:

- Seat swivel and height adjustability.

- Enough space under the chair to allow the knees to flex, allowing the hip to extend, which maintains the curvature of the lumbar spine and reduces tension in the spinal ligaments and wedging of the intervertebral discs.
- A backrest is needed for stability of the trunk.
- The seat pan should also have a slight hollow to prevent the pelvis from sliding forward.
- Extra cushion should be used to support the lumbar region.
- The armrests should be at an appropriate height to support the lower arms.

FEATURES

Jindo et al. (1995) stated that there are five main components of a chair, namely the backrest, back support, seat pan, armrest and supporting shaft.

The same author stated 16 other chair factors relevant for chair design such as:

- Whether the back rest and seat are attached or separated
- The back rest form, which includes a high, low, narrow or wide back
- The shape of the back rest, such as round and square
- Curve of backrest
- Backrest thickness
- Backrest fabric cover
- Shape of the seat
- Aspect ratio of the seat
- Seat area
- Curve of the front of the seat
- Seat cushioning
- Shape of armrest
- Cross-sectional shape of shaft
- Base geometry
- Thickness of base pieces
- Back support design

There are many aspects that need to be considered when designing a chair and from all these characteristics, a number of different chairs have been manufactured. However, none of these chairs seem to incorporate the anthropometry of the South African population.

SEAT PAN TILT AND BACKREST INCLINATION

Chairs were previously designed for individuals to be seated upright at 90 degrees however; this has changed as it positions the body in an unnatural posture (Mandal, 2013). This upright sitting results in fatigue, discomfort and poor posture. A seat pan that encourages a tilted forward angle maintains the natural curve of the spine. A chair with a tilted seat pan and an inclined backrest ensures balancing of opposing muscle groups, natural curvature of the spine is maintained, the angle between the trunk and thighs are greater than 90 degrees which allows for greater mobility and relieves pressure on the lungs and stomach (Mandal, 2013).

Zenk et al. (2012) found a relation between comfort of seated posture and pressure within the vertebral column. When seated upright at 90 degrees the pressure on the discs was the greatest (1.6bar) and this resulted in discomfort however when the individuals were seated at an inclination, the pressure went to 0.5bar. Therefore sitting on a chair with a tilted seat pan and backrest, the pressure in the spine is reduced compared when seated at 90 degrees or less. Goossens and Snijders (1995) also found that at specific seat and backrest inclinations, there are acceptable shear forces on the intervertebral discs. Therefore with respect to both pressure of the intervertebral discs and comfort, a seat pan and backrest inclination should be chosen between 90 and 95 degrees. The seat pan tilt and the backrest inclination are important features of chair design as it ensures a natural spinal curve is maintained while seated.

TASK CHARACTERISTICS

Groenesteijn et al. (2009) stated that an office chair is a single component in a complex work environment. Kroemer (2009) stated that there are three main factors that need to be taken into account to create an ergonomic workstation. These three factors include the visual interface, which refers to the keyboard positioning and the monitor screens and how far the user is situated from these items. The second factor relates to the manipulation of items such as the keyboard and telephone. The third factor is the office chair and the body support that it provides. Therefore, it is not only the comfort of the office chair that is important, but also the first two factors that allow for a comfortable working environment (Kroemer, 2009).

The task determines the activity and the posture the individual has to maintain. The task characteristics influence the seat characteristics, as the seat design needs to support the posture of the individual while he or she performs a task (Pheasant and Haslegrave, 2006). The seat needs to be adjusted to the task the individual is performing, as different activities require different movements ranges (Bridger, 2003). Kroemer and Grandjean (1997) stated that the office chair needs to adapt to both the traditional office job and the modern equipment of information technology.

OFFICE CHAIRS

CONVENTIONAL OFFICE CHAIR

Office chairs can be classified as either a static, dynamic or synchronized office chair. “Conventional office chairs” are chairs that have a seat pan, backrest support and/or armrests (Bujaryn, 1994). They are the most popular and widely used chairs in the office and working environment. The negative effect of the conventional chair is that the individual maintains a static posture. Users often find it uncomfortable after some time, which results in the user fidgeting, leaning forward and backwards every few minutes (Bujaryn, 1994). Abeysekera (1985) stated that the seat pan needs to be designed for most of the population and still add 12cm to the dimension to allow for the individual to change postures while seated on the conventional office chair. According to Dungan (1984), the conventional chair causes the legs to be at a 90^0

angle to the upper body. By doing so, the pressure beneath the buttocks can be distributed over a large region (Pheasant, 1996).

Bendix et al. (1985) designed a chair that gave users the ability to “rock” backwards (5 degrees) and forwards (10 degrees), which is also known as a “dynamic chair”. This prevented postural fixation as individuals cannot be seated statically for a long period before fatigue and discomfort occurs. Udo et al. (1999) also found that with tilting seats, back discomfort was reduced as there was a reduction in the static back muscle activity compared to the fixed office chairs. According to Bridger (2003), dynamic office chairs are preferred rather than the fixed office chairs. Sondergeld (1988) created the adjustable back and seat height mechanism that adapts according to the individual’s weight. The pressure that an individual applies to the backrest and seat while sitting will cause the structures to move by means of a cam system and therefore adjust to suit the individual. This allows the individual to change postures while seated and reduces the discomfort.

Another investigation was done by van Deursen et al. (1999) relating to the effect of a conventional chair with a rotational function. The chair had an angle of axial rotation of 1.25^0 and a rotational frequency of 0.2Hz and 0.08Hz. Van Deursen et al. (1999) concluded that low frequencies of seat rotation have a beneficial effect on LBP. There was also a significant increase in spinal length when seated on the rotational chair compared to the static chair as the rotation reduces the pressure in the nucleus pulposus, allowing sufficient nutrients to be supplied to the intervertebral disks. Conventional chairs have been designed with adjustable features in order to reduce LBP caused by a static seating posture (Benedix *et al.*, 1985; Udo *et al*., 1999 and van Deursen *et al.,* 1999). Galinsky et al. (2007) stated that frequent rest breaks during office work minimised musculoskeletal discomfort and eye strain. However, with seat rotation, this will result in postural changes and, therefore, a reduction in LBP so that the individual can continue working without being interrupted (Benedix *et al.,* 1985; Udo *et al.,* 1999 and van Deursen *et al.,* 1999).

Office chairs are becoming more and more dynamic in order to reduce discomfort while seated for long durations (Roslund, 1999). The synchro-tilt type chairs are

becoming more favorable as the backrest tilts synchronously with the seat assembly but at a greater rate (Roslund, 1999). The backrest and seat pan adjust and tilt at the same time. These chairs also have a weight mechanism so that one can apply one's own body weight on the backrest and can experience a "rocking" back and forth motion. The adjustments on the synchro chairs are more freely movable and includes more adjustments compared to the dynamic chairs (Roslund, 1999). The seat pan length adjustment and armrest width and pivot angle adjustments are other important features of the synchro chair.

Figure 1: Dynamic office chair: Model 'Midback' (taken from Ergotherapy, 2009)

KNEELING OFFICE CHAIR

The "kneeling" seat is a seat designed to maintain an erect spine and lumbar curve by tilting the pelvis by the forward tilt of the seat and supporting the knee and lower leg (Dungan, 1984). However, there are negative aspects to this seat design, as the effect of gravity causes the individual to slide forward and the knee support is the only feature supporting the body (Bujaryn, 1994). As the knee did not develop to support the body while sitting, pressure on the knees and pain will occur for many individuals. Ergonomically correct sitting posture requires the legs to be in a relaxed state, which is not the case with this chair. The design of the kneeling chair does provide an erect posture; however, individuals seldom maintain this posture. The tendency is to lean forward and to the side, and this places excessive amount of stress on the muscles that are supporting the upper body, therefore causing fatigue faster (Bujaryn, 1994).

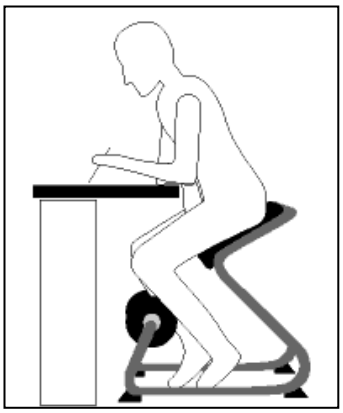

Figure 2: Kneeling chair (taken from CCOHS, 2007)

SADDLE CHAIR

Toren and Oberg (2001) stated that the “saddle chair” maintains the same posture as being seated on the back of a horse. It maintains optimal hip-trunk angle and knee angle at approximately 135^0 (Keegan, 1953). This places the lumbar spine near the mid-range of motion, which is an advantage as other office chairs place posture near the outer range of joint motion, which should be avoided. The “saddle chair” has been reported to reduce the discomfort in the lower back as this chair causes the spin to be less kyphotic and the pelvis inclination remains almost unchanged compared to sitting on a conventional chair (Bendix *et al.,* 1985). This chair does, however, cause discomfort in the buttocks and knee region and may also have implications for the female dress code (Bujaryn, 1994).

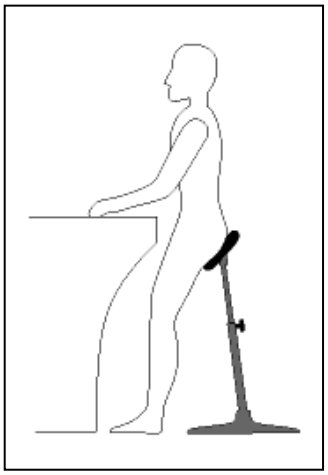

Figure 3: Saddle chair (taken from CCOHS, 2007)

FORWARD SUPPORT CHAIR AND THE VARIABLE POSTURE CHAIR

The “forward support” chair is similar to the kneeling chair, although the knees do not support the forward lean of the body but the torso (Bujaryn, 1994). The seat supports the user in an upright or forward posture. The support system allows the muscles to stay relaxed and the spinal column to maintain neutral curves. Additional features such as the head chin and forehead supports can be fixed in place to support the weight of the head (Seber, 1985). The negative aspect of this chair is that the support places pressure on soft tissue of the body and also creates a static working posture (Seber, 1985)

The “variable postural” chairs allow the user to maintain two distinct body postures, namely forward and backward (Bujaryn, 1994). The user can alter the posture depending on the preference. The forward and backward tilt is supported by a vertical plane. The negative aspects of this chair are that the surface of support differs depending on the forward or backward posture (Bujaryn, 1994). A greater support plane is needed for the back rest and, therefore, it is too large for the chest/torso support. The chest support is mounted on a centre support with is directly between the legs and therefore, the individual has to straddle the chair. This has an implication for females especially those wearing dresses. Another negative aspect of the chair is that the user needs to reverse the chair physically.

Figure 4: Forward support office chair: Twist chair (taken from Bēhance Served Sites, 2012)

SWISS BALL/ GYM BALL

Gym balls/Swiss balls have been a popular type of devices implemented in training programmes and rehabilitation programmes (Merritt and Merritt, 2007). The positive aspects of the Swiss Ball as an office chair is that it promotes balance and therefore results in an increase in spinal stability. It also allows for the individual to move freely on the ball. However, there are also draw-backs to using the Swiss Ball such as muscle fatigue due to the muscles constantly contracting to maintain stability especially without the support of a backrest (Rehan, 2010) The ball is also unstable and this could result in injuries at the workplace as an individual could slide off the ball and collide into other office equipment (Merritt and Merritt, 2007). Frequent breaks are required when using the Swiss Ball in order reduce fatigue. The frequent rest breaks could result in distractions for office workers especially if deadlines need to be met (Rehan, 2010). Swiss Balls do not provide armrests, which reduce the tension in the neck and shoulders.

Figure 5: Swiss ball (taken from Livestrong.com, 2011)

A quality conventional ergonomics office chair provides the best support for long-term sitting postures (Rehan, 2010).

VARIATION IN POSTURE DUE TO CHAIR DESIGN

The main reason why there are so many different chair designs is because the previous chair designs caused body discomfort. Therefore a different chair design was manufactured, which had different features to the previous chairs in order to compensate for the discomfort previously felt. However, overtime this chair design also caused body discomfort due to the fact that the individual maintained a particular posture while seated in that chair. Maintaining a static posture will eventually lead to discomfort as the body is meant to move. Wilke et al. (1999) stated that the body needs to be able to move or should move as this promotes the flow of fluid (nutrition) to the discs and reduces intervertebral pressure.

Therefore a fixed design, fixed chair will result in discomfort (Leuder, 2004). Seated posture constitutes a risk factor for lower back pain (van Dieën *et al.,* 2001). This is caused from monotonous mechanical loading on the body by a fixed seated posture. Static postures increase discomfort and health risks, chronic disorders such as joint impairments, muscle pain, impaired circulation and tissue damage. Varying postures while seated for prolonged duration will reduce the loading on the body by slightly changing postures while seated and this can be achieved by the design of an office chair. Dynamic office chairs will adjustable backrests and seat pan, move in a fixed ratio with respect to each other or can move freely. The dynamic chairs are shown to have a potential advantage over static chairs as the stature after working and sitting on the chairs showed a larger stature gain therefore spinal shrinkage was not as greatly affected than when sitting on a static chair for the same duration.

Leuder (2004) also stated that it is the lack of variety of postures that is more hazardous than the sedentary nature of the work the individual is performing. Therefore it is seen that chair design is moving from a “static chair” to a more

“dynamic chair” so that the individual can constantly change postures while seated to reduce the discomfort felt in previous posture.

AESTHETICS

Colour affects the mood and feelings of an individual. Colour is subjective and effects may differ according to individual preferences (Park and Han, 2003). Depending on personality, colour can either attract or irritate (Bellizzin *et al*., 1982). Physical attraction may be affected by colour and the attention-grabbing power of colour may influence the decision to purchase. Colour can also distract the individual if it is too bright or an unpleasant colour, which will result in the individual not buying that specific item. Niku (2009) states that colours create specific moods such as black, grey and yellow-green create a neutral effect, while white creates a neutral to positive effect and red and orange create a positive effect. Yellow creates a cheerful, warm effect; green has a restful, serene effect; blue has a subduing effect and purple had a solemn effect. The desired corporate image of the workplace may influence colour choice as might the suggestion of power, where a larger bolder chair may be found suitable for the employer while a smaller, simpler chair may be selected for the employees (Niku, 2009).

Different cultures assign different identities to various colours (Bellizzin *et al*., 1982). Colour has become a symbol in many cultures and has even separated cultures (Varley, 1980). The same author stated that bright colours and patterns have been used for identity especially in the African population. Thus it would seem that appearance is as important in the design of an office chair as is functionality (Park and Han, 2003). The same author states that appearance plays a huge role in subjective satisfaction and comfort. Therefore, designing a chair with specific colours and patterns that relates to the population’s cultural values and identities may improve subjective satisfaction and lead to the perception of a more comfortable chair. It is well documented that personal comfort and satisfaction are closely linked to work output and productivity (Park and Han, 2003).

RISKS OF USE

Work-related musculoskeletal disorders (WRMSDs) are increasing in the workplace due to increased job demands, repetitive motions, incorrect postures, static postures and a lack of ergonomic initiative (Robertson *et al*., 2009). The same author states that increasing the number of hours spent at the computer and inappropriate seating will result in discomfort and eventually lead to WRMSDs. Back pain and leg pain are the leading issues associated with incorrect seating. However, many more problems are related to bad seating and incorrect posture, namely increased immobility, which leads to lower back pain and intervertebral disc degeneration (Robertson *et al*., 2009). Also prolonged static postures while seated cause strain on ligaments, tendons and muscles and can also lead to reduced blood flow to the lower extremities. Therefore, static or immovable postures can only be maintained for a short duration before the individual feels discomfort (Bridger, 2003). A study done by Tulder *et al.* (1995) stated that musculoskeletal disorders are the 5th most expensive disease regarding hospital care and the most expensive regarding absenteeism and disablement. One third of the hospital costs and a half of the absenteeism and disablement are due to back pain. The total direct medical cost in 1991 was estimated to be US$367.6 million (Tulder *et al.,* 1995).

DISCOMFORT

Comfort is defined as well-being, items which bring bodily ease and freedom from pain (Vink, 2005). Comfort is a subjective phenomenon and is affected by various physical, psychological and physiological factors (Looze *et al.,* 2003). There are many assessment techniques for measuring comfort or discomfort perceived while seated. Corlett and Bishop's (1976) subjective rating method is used to measure body discomfort. The Body Discomfort Map presents body areas where pain can be felt, which allows subjects to indicate the actual discomfort areas. Shackel *et al.* (1969) stated the Chair Feature Checklist, which is a technique that assesses the structure of a chair that causes discomfort. This can lead to the removal or adjustment of specific features on the chair. Chair Dimensions and Standard Recommendations focus on whether the current chair has incorporated the standard

recommendations and whether the user's anthropometry has been considered. This is an important aspect of chair design (Shackel *et al.,* 1969).

Vink (2005) developed a Comfort Model, which includes factors such as the individual's history and previous knowledge of comfort of objects. The individual's state, such as mood, emotions and feelings, determine the evaluation of an object, and visual input such as the first impression is the most important. Therefore, when designing a chair, all sensory modalities need to be considered and anthropometric dimensions need to be included in order to maintain comfort (Vink, 2005 and Shackel *et al*., 1969).

DURATION OF COMFORT RANKING

According to Pheasant and Haslegrave (2006), physiological responses and discomfort increase with time, therefore it is not the first impression that counts most when choosing a chair, but comfort after sitting in the chair for a period of 5 to 30 minutes - this will result in an appropriate decision about a chair. However, Fernandez and Poonawala (1998) stated that it would take 3 hours of sitting to obtain a correct rating of comfort for a chair. Cosmi *et al*. (2008) measured the comfort of six office chairs by requiring the participants to be seated on each chair for 20 minutes and with subjective measures of comfort and the chairs were ranked according to comfort. However, Lee and Ferraiuolo (1993) stated that testing of chair comfort will involve the participant being seated on the chair for up to 8 hours to obtain the most accurate measures of chair comfort. The same authors also stated that meaningfulness of evaluations increases with an increase in test duration. Therefore, the longer the test duration, the more accurate the measures will be. Helander and Zhang (1997) stated that ranking chairs in order of comfort and discomfort can be done in a few minutes. However, physiological responses might not have set in yet and this can result in an incorrect ranking of comfort and discomfort (Pheasant and Haslegrave, 2006).

According to Vink (2005), there is a connection between comfort and ergonomics. Ergonomics strives for optimal human performance and designing for comfort with the human operator as priority. End users need to be a part of the design process,

such as obtaining dimensions for the product, as this will ensure comfort. The interaction process with the end users is known as participatory ergonomics (Vink, 2005). The same author stated that there is a need for ergonomists to pay attention to the emotions of the user as comfort is also related to the emotions and will affect the outcome of a design. Comfort is affected by the state that an individual is in; therefore it can have a negative effect on comfort if the individual is upset, aggravated or sad, or a positive effect if the individual is happy and excited (Vink, 2005).

INJURIES DUE TO SITTING

LUMBAR LORDOSIS

When an individual is standing, the natural curve of the spine is maintained; however, when the individual sits with a 90^0 thigh angle, the lumbar region of the spine flattens out (kyphosis) and may even cause an outward bend (Sanders and McCormick, 1993). This occurs due to the hip joint rotating about 60^o, forcing the pelvis to tilt backwards about 30^0 in order to achieve a 90^0 thigh angle. As the pelvis tilts, added weight is placed on the intervertebral discs which may lead to lower back pain or intervertebral disk degeneration (Sanders and McCormick, 1993). The same authors stated that by having a forward-tilted seat which creates a more relaxed posture and decreases the lordotic effect. However, according to Bridger (2003), with a forward-tilting chair, the individual shows a typical erect but slumped posture and this can be corrected by having a tilted work surface. According to Groenesteijn *et al.* (2009) a lumbar support is needed to maintain the natural curve of the spine and therefore, it is important that every chair is equipped with one. Furthermore, it needs to be adjustable to the physical dimensions of the user in order for comfort to be achieved.

IMMOBILITY AND CIRCULATION

Discomfort can occur due to repetitive movement or immobility while working in the office environment (CCOHS, 2007). Repetitive injury could be caused by frequently rotating the neck to focus on a document on the desk and then focusing back on the monitor screen. However, sitting at a desk will cause the individual to be in a static

posture which more than likely leads to back discomfort. Humans are made to move and immobility for a long duration will eventually lead to discomfort (CCOHS, 2007).

Static postures result in aching, cramping, and serious circulation-related problems in the long term (Sanders and McCormick, 1993). When the body is static, there is reduced blood flow to the parts of the body such as the shoulders and lower back while sitting (Sanders and McCormick, 1993). The same authors stated that postural fixity also affects the blood flow to the legs, resulting in swelling and discomfort. Discomfort and swelling in the legs also result from the seat being too high for the individual (feet hanging freely and not placed on the ground), which stops the circulation of blood flow as pressure is placed on the back of the thighs or knees (Bridger, 2003). There are ways to reduce postural fixity, such as allowing the user to rock in the chair, which is made possible by using dynamic chairs that allow for rotation and tilting of the backrest. The chair should also be able to be adjusted to suit the specific anthropometry of the individual, allowing for a more comfortable seated posture. Work can still continue if the individual incorporates slight chair movement when discomfort arises due to sitting compared to disembarking the office chair to stretch every few minutes. This could also lead to other employees becoming distracted (Sanders and McCormick, 1993).

LOWER BACK PAIN AND INTERVERTEBRAL DISK DEGENERATION

Wilke et al. (1999) conducted a study on intradiscal pressure on one individual who performed various tasks. It was found that intradiscal pressure was actually lower when sitting than when standing as the activation of muscles increases pressure on the spine. However, there are many problems that occur with sitting especially for long durations. The most severe problem with sitting is its effect on the spine and the muscles of the back (Kroemer and Grandjean, 1997). When sitting, the muscles of the back are stressed. The most common cause of back pain involves the intervertebral discs degenerating and losing their strength with age. During the degenerative process, the vertebral column may become deformed (Kroemer and Grandjean, 1997). The same authors stated that increased disc pressure may result from the pelvis rotating backwards, the sacrum turning upright and the vertebral column changing from lordosis to straight or kyphotic shapes, all due to sitting. A few

ways of reducing disc pressure include increasing the seat angle by leaning either forward or backward with an upper limb support (Kroemer and Grandjean, 1997), or having proper lumbar support (Sanders and McCormick, 1993).

NECK PAIN

A study done by Ariëns et *al*. (2001) observed factors for neck pain. The study looked at what factors (neck flexion, neck rotation and sitting) could lead to neck pain. The study found that there was a significant positive relation between neck pain and sitting 95% of the working day. There was also a positive relation between neck pain and neck flexion with individuals working with a minimum neck flexion of 20 degrees for more than 70% of the working day. However there was no relation between neck rotation and neck pain. This could be due to neck rotation being a dynamic movement as it reduces the static loading of ligaments, tendons and muscles whereas sitting and neck flexion at a specific angle for long durations poses this risk (Robertson *et al*., 2009).

USER CHARACTERISTICS

Characteristics of the user that must be considered when designing the optimal chair include the following: anthropometry, discomfort, circulation, pelvic stability, blood flow, lower back pain and emotions (Kroemer and Kroemer, 2001). The duration of seating, physical demands on the seated operator as well as the associated cognitive demands are “task” characteristics but no less important to consider during this process (Kroemer and Kroemer, 2001). These aspects and the applications of ergonomic principles to chair design will enable the design of an appropriate chair for an individual, which will assist in reducing or eliminate altogether the negative aspects such as discomfort and pain, reduced blood flow, lower back pain and pelvis tilt, which individuals experience while working in front of a computer with the incorrect seating posture (Kroemer and Kroemer, 2001).

ANTHROPOMETRY

Anthropometry is the measure of human body dimensions and other physical characteristics such as volume, mass of segments and centre of gravity (Sanders and McCormick, 1993). Anthropometry can be measured when the individual is performing either a static or a dynamic task. According to Sanders and McCormick (1993), static dimensions are measurements of the body while in a fixed position and dynamic dimensions are measurements of the body while engaging in physical activity. Therefore, when designing items or objects, engineers need to incorporate the human anthropometry and postures of the individual as well as the activities that the individual is required to perform while in the specific environment.

Anthropometric dimensions are specific to populations and may be geographically, climatically or ethnically influenced. It follows that one design does not fit everyone and ideally the specific dimensions of the end-user population must be taken into consideration during the design phase (Kroemer and Kroemer, 2001). Most anthropometric dimensions currently available emanate from North America and European populations. By virtue of the fact that technology and design is advanced in these First World countries, the anthropometric variables have been applied universally, no matter which population is to use the end-product. The transfer of a design or technology from one culture to the next does not always suit the user group of a specific culture and country (Gurr *et al.,* 1998). Dimensions from other populations are not taken into account and this is the leading cause of discomfort in chairs. Individuals have different body dimensions and their specific ranges in furniture dimensions and adjustments and working habits are different around the world. Body measurements differ due to age, gender, ethnicity and the activities which the individual performs (Sanders and McCormick, 1993). Chair dimensions need to be modified to suit the local user, not just the North American and European user (Kroemer and Kroemer, 2001). Therefore, focusing on anthropometric data before designing a chair will help to eliminate the cause of discomfort (Groenesteijn *et al*., 2009).

The anthropometric data used for designing an object should be representative of the population intended to use the item (Sanders and McCormick, 1993). These authors

state three general principles for applying anthropometric data. These include: designing for extreme individuals, which states that one should include the maximum and minimum values of the population; designing for adjustable ranges, and to provide comfort and support (Sanders and McCormick, 1993). Ergonomists aim at designing for the individual and for physical, mental and social aspects. Therefore, when designing seating, correct representation of the population needs to be taken into account, to eliminate incorrect and harmful transfer of technology and designs (Gurr *et al.,* 1998).

ANTHROPOMETRIC DIMENSIONS FOR CHAIR DESIGN

It is challenging to design equipment and workstations due to the enormous variations in body sizes (Kroemer and Grandjean, 1997). Office chairs include percentiles to design the specific structures of the chairs according to the anthropometry of the user (Kroemer and Grandjean, 1997). The fifth percentile (5th%ile), fiftieth percentile (50th%ile) and ninety-fifth percentile (95th%ile) are often of design interest (Kroemer, 2009). The 5th%ile is the smallest 5% of the total data and it considers the reach constraint (Pheasant and Haslegrave, 2006). Designing according to the 5th%ile takes into account the maximum acceptable dimensions for the smallest individuals to perform an action. The 95th%ile is the largest 95% of the total data and it is important to design for clearance (Pheasant and Haslegrave, 2006). Therefore it informs designs regarding the minimum acceptable dimensions. This allows for the larger sector of the population to achieve comfort while also accommodating the smaller population. The 50th%ile is also known as the average of the total data (Kroemer, 2009).

There are standard measuring techniques for different structures of chairs (Pheasant and Haslegrave, 2006). Measuring anthropometrical data while seated will require the individual to maintain a standard sitting posture, which entails the individual sitting up straight, on a horizontal, flat surface, looking straight ahead, shoulders relaxed, arms hanging by the side, elbows at 90 degrees and forearms horizontal, and the height of the seat is adjusted until the knees are at 90 degrees (Pheasant and Haslegrave, 2006). According to Openshaw and Taylor (2006), Cosmi *et al*.

(2008) and Abeysekera (1985), there are specific anthropometric measurements that need to be taken to design an office chair.

SEAT MEASURES

The seat height/popliteal height is determined from the floor to the popliteal. According to ISO 7250 (2008), lower leg length or popliteal height is the measurement from the floor to the lower edge of the thigh behind the knee, which is positioned at 90 degrees. Shoe allowance must also be included in the height. Pheasant and Haslegrave (2006) stated that 25mm should be included for females and 45mm should be included for males to accommodate for shoes. The area below the seat should allow for adequate leg and foot movement. The best compromise for seat height would be the 5th%ile; however, it would be ideal for the seat height to be adjustable between the 5th%ile and 95th%ile; furthermore, it should be appropriate to the height of the desk or table (Pheasant and Haslegrave, 2006). Shoes were not considered when measuring stature therefore it was not included when measuring popliteal height.

The seat depth/leg length is the measure from the popliteal to the posterior edge of the buttocks (Openshaw and Taylor, 2006). ISO 7250 (2008) also stated that the buttock-popliteal length or seat depth is measured from the rearmost point of the buttocks to the popliteal. The seat depth (buttock-popliteal length) should be designed according to the 5th%ile to allow for smaller users to be able to use the backrest effectively (Pheasant and Haslegrave, 2006). According to ISO 7250 (2008), hip breath or seat pan width/hip width is the measurement of the widest portion of the hips while seated. The participant's thighs are fully supported and the knees are together and feet hanging freely. Seat pan width needs to include clothing allowance. According to Pheasant and Haslegrave (2006), the seat width would take into account the 95th%ile of hip breath, in order to allow for movement and to allow for clothing.

BACKREST AND LUMBAR SUPPORT MEASURES

The lumbar support is positioned over the lumbar region within the limits of the second to fifth lumbar vertebrae, to allow adequate free movement. The lumbar support height is the distance from the seat pan to the lumbar curvature. By placing the support over this region, will maintain the natural curvature of the spine while seated (Openshaw and Taylor, 2006). The backrest height is the distance from the seat pan to the scapula and the backrest width is the hip breath and includes clothing allowance. The necessary adjustments for the backrest and lumbar support should be provided in order to suit all individuals. Therefore, the backrest and lumbar support heights should range between the 5th%ile and 95th%ile in order to create a comfortable office chair (Pheasant and Haslegrave, 2006).

ARMREST MEASURES

Armrest height/ elbow height is the vertical distance from the seat pan to the lowest bony part of the elbow while it is bent at 90 degrees. The participant needs to be seated fully erect with relaxed shoulders and the lower arms should be horizontal (ISO 7250, 2008). Elbow-wrist length or the armrest length/ arm length is measured from the ulnar styloid process to the wrist while the forearms are horizontal (ISO 7250, 2008). The distance between the armrests is determined by the hip width and must include clothing allowance, while the participant is seated (Openshaw and Taylor, 2006).

Chair Structures	
Seat Height	A
Seat Length	B
Seat Width	C
Backrest Height	D
Backrest Width	E
Backrest Lumbar support	F
Armrest Height	G
Armrest Length	H
Between Armrests	I

Figure 6. Chair dimensions for office chair design (Taken from Openshaw and Taylor, 2006).

Figure 6 represents the different office chair dimensions and the measuring proportions of each structure according to Openshaw and Taylor, 2006.

A study done by Kroemer and Grandjean (1997) on office chair dimensions in the United States and Onuoha et al. (2012) on agricultural farm workers in Nigeria represented the difference in anthropometric measurements for males and females respectively.

Table I: Human dimensions determining office dimension for the United States (Kroemer and Grandjean, 1997).

Human Dimensions	Male	Female
Seat Length / Buttocks-Popliteal length (mm)	500±27	481±27
Seat Height / Sitting Popliteal height (mm)	433±25	389±24
Seat Width / Hip breath (mm)	365±25	383±27
Armrest Height / Elbow height (mm)	232±27	221±27
Armrest Length / Elbow - Finger length (mm)	483±23	442±23
Sitting Shoulder Height (mm)	598±30	555±29
Shoulder Breadth (mm)	491±26	431±23

50^{th}%ile and standard deviations for office chairs dimensions for the US male and female population (1989).

Table I includes the suggested human dimensions for office chairs for males and females in the United States. All the male office chair dimensions are greater than the female office chair dimensions. A study by Onuoha et al. (2012) was conducted on Nigerian farm workers (n=300), to obtain body dimensions for the design of farm equipment. 30 anthropometric dimensions necessary for farm equipment design were collected, of which 10 are represented in Table III as these 10 relate specifically to this study of office chair design.

Table II: Comparing body dimension of male and female Nigerian, agricultural workers (Taken from Onuoha *et al.,* 2012).

Body Dim.	Male (n=300)					Female (n=200)				
	Mean	Range	Percentiles			Mean	Range	Percentiles		
			5th	50th	95th			5th	50th	95th
Body Stature (cm)	163.4 (50.84)	148.30-182.10	158.90	163.60	176.60	156.80 (5.28)	145.30-173.50	149.10	156.50	168.00
Body Weight (kg)	56.70 (7.14)	48.30-71.80	41.30	56.30	66.30	51.30 (4.91)	35.00-71.30	39.40	51.20	65.80
Waist circum. (cm)	70.60 (4.48)	68.20-95.90	68.60	83.50	90.40	73.00 (6.20)	68.10-98.00	70.40	87.80	92.50
Hip circum. (cm)	29.00 (1.58)	27.30-36.30	28.50	30.80	35.60	29.60 (2.43)	28.20-43.40	32.60	37.50	41.10
Shoulder height (cm)	138.40 (4.91)	127.00-149.10	129.30	138.20	195.60	129.10 (4.92)	122.00-133.70	125.30	128.20	130.20
Armrest height (cm)	24.30 (3.70)	17.40-31.50	19.60	26.80	29.50	17.90 (1.44)	14.10-21.30	15.10	17.80	19.20
Popliteal/ Seat Height (cm)	43.40 (3.35)	38.20-57.60	39.50	43.30	52.10	39.50 (2.16)	36.10-42.50	37.10	38.70	40.20
Seat Length (cm)	48.20 (2.64)	33.70-59.30	42.60	49.10	53.50	43.20 (2.71)	37.20-45.90	39.00	41.80	43.90
Thigh clearance (cm)	13.50 (0.92)	10.50-16.30	11.40	13.60	15.70	9.10 (0.98)	7.60-14.90	8.10	9.40	12.80
Seat width (cm)	29.00 (1.58)	27.30-36.30	28.50	30.80	35.60	29.60 (2.43)	28.20-43.40	32.60	37.50	41.10

Dim =dimensions; circum. = circumference

Table II represented the 5th%ile, 50th%ile and 95th%ile dimensions for office chair structures for Nigerian agricultural workers. The male sample had greater anthropometric values compared to the female sample, except for three measures, namely waist circumference, hip circumference and seat width.

SOUTH AFRICAN POPULATION SPECIFIC ANTHROPOMETRY

According to the 2010 census, South Africa is made up of 79.4% Africans, 9.2% White, 8.8% Coloured and 2.6% Indian/Asian (Lehohla, 2010) population groups. The Whites and Indian/Asian South African population generally live in urbanised

areas, whereas the Africans are largely rural, however this trend is changing as people become urbanised. South Africa is a developing country and the common trend in the nutritional status has been that many children are malnourished. However, adults are increasingly obese (Puoane *et al*., 2002). This is a great concern especially regarding women living in developing countries as they are affected the most. Many females are becoming obese due to cultural beliefs as it is assumed that an overweight or obese individual is a healthy individual and not affected by the Aids virus. There is also a perceived link between ample body size and childbearing ability (Groenesteijn *et al*., 2009). South Africans' physical dimensions have increased over the years due to dietary changes and physical performance. Anthropometric measurements have increased between age groups, within age groups, genders and different cultures (Jung, 2005).

Puoane et al. (2002) state that the body mass index (BMI) indicates overweightness and obesity (≥25kg/m^2 for males and ≥20kg/m^2 for females) and Waist to Hip Ratio (WHR) indicates abdominal obesity (WHR ≥1.0 for males and WHR >0.85 for females). 29.2% of South African males were overweight or obese (≥25kg/m^2) according to Puoane et al. (2002), and according to the South African Demographic Health Survey in 2003, 29% of the South African males were overweight and 8% were obese. Puoane *et al*. (2002) stated 56.6% of South African women were overweight or obese (≥20kg/m^2). The South African Demographic Health Survey published in 2003 states that 59% of the South African females were overweight and 23% were obese. Puoane *et al.* (2002) states that 9.2% of the male population displayed abdominal obesity and 42% of the female population displayed abdominal obesity. Jansen et al. (2004) stated that BMI is not the only predictor of health risks. Waist circumference, along with BMI, is an improved predictor of health risks such as chronic diseases, which include type 2 diabetes, cardiovascular diseases (CVD) and stroke.

Due to increasing urbanisation and the increasing weight gain in the South African population, office equipment needs to be redesigned, especially an item such as the ergonomic office chair (Puoane *et al*., 2002). Mandal (1981) also states that specific anthropometric data is needed for the design of a population-specific office chair for

South Africans due to their unique anthropometric dimensions. As anthropometric measurements of individuals get larger, designs of chairs need to be changing constantly to reflect the varying anthropometry. If the anthropometry of the county is not considered when manufacturing office chairs, it will lead to discomfort and eventually musculoskeletal disorders (Groenesteijn *et al*., 2009).

CHAPTER III

METHODOLOGY

INTRODUCTION

The purpose of this study was to obtain anthropometric data specific to the South African population for the design of office chairs specific to the characteristics of this diverse population. This study would supply guidelines for office chair manufacturers pertaining to seat height, seat pan, backrest, lumbar support and armrest dimensions.

EXPERIMENTAL DESIGN

An anthropometric measuring chair was designed by the Human Kinetics and Ergonomics department to collect measurements of office chair dimensions as well as data on a number of participant characteristics. South Africa is a diverse population with a number of ethnic groups (Black, White, Coloured and Indian/Asian). 683 individuals participated in the study from a number of companies around South Africa. A large sample size was selected to procure reliable data from each ethnic group. Companies were situated in Johannesburg, Pietermaritzburg, Durban, East London, Uitenhage and Cape Town.

EXPERIMENTAL MEASURES

ANTHROPOMETRIC CHAIR

Designing of an anthropometrical measuring chair according to the pilot test data was the first task prior to data collection. The Human Kinetics and Ergonomics department had previously designed an anthropometric chair for study purposes within the department. The redesign of the anthropometric chair was adjusted to fit the specific sample group, South African population, which was chosen for the

research. The measuring chair was constructed in a way that allowed the three separate parts of the chair to be dissembled to facilitate easy transportation. It was also adjustable in order to measure armrest height, armrest length, and distance between armrests, seat height, seat width, seat depth, backrest height, backrest width and lumbar support height.

Figure 7. Anthropometric measuring chair.

Tape measures were glued to the seat pan to ensure reliable capturing of measurements of the seat depth and seat width during data collection (Figure 7). One was glued onto the seat pan from the anterior to the posterior, and passing through the center of the seat pan. Two tape measures were glued from the center of the seat to the outermost part of the seat pan.

ANTHROPOMETRIC CHAIR MEASUREMENTS

The anthropometric chair measurements taken included the backrest, lumbar support, armrest and seat dimensions. The seat pan dimensions included 4 measurements; 4 measurements were taken for the backrest dimensions; lumbar support dimensions included 3 measurements and 2 measurements were taken for the armrest dimensions.

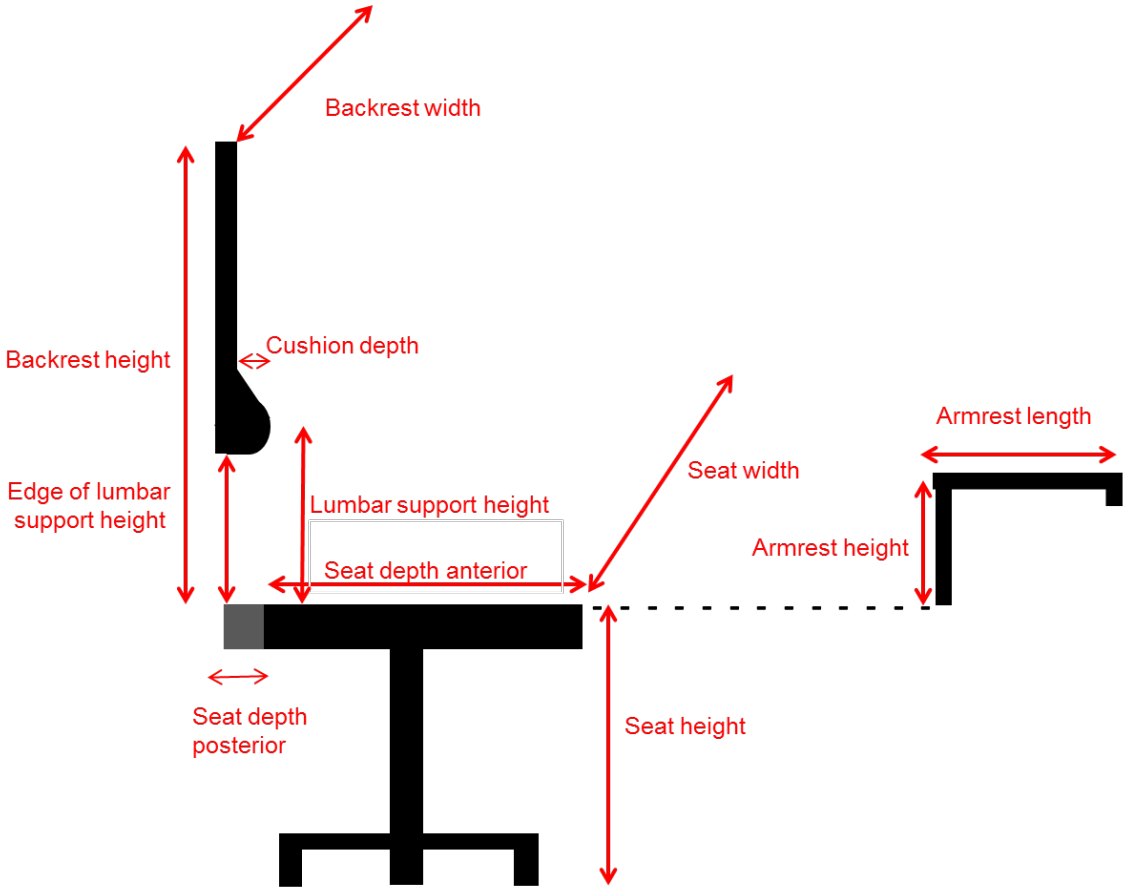

Figure 8. Indicates the anthropometric chair measurements that were collected

SEAT PAN MEASUREMENTS

Seat height/Popliteal height was taken from the floor to each participant's popliteal, while the knees were bent at 90º. Participants removed their shoes for this measure. Seat depth anterior/ Leg length was measured from the edge of the anterior aspect of the seat pan along the seat pan until the vertical point of the lumbar support feature on the seat pan. Seat depth posterior/ Buttocks was taken from the vertical point of the lumbar support feature on the seat pan to the edge of the participants' buttocks. Seat width/Hip width was calculated by adding the readings of the two tape measure readings on the side of the hips, on the seat pan. Thigh height was measured with a plastic ruler from the seat pan to the highest part of the thigh while seated.

BACKREST AND LUMBAR SUPPORT MEASUREMENTS

Backrest height was recorded vertically, from the seat pan to the scapula with a plastic ruler. Hip breadth while seated indicated the measurement for backrest width. Lumbar support was placed between the 2nd to 5th vertebra, depending on the participant and their body proportions, and the lumbar support height was recorded by measuring from the seat pan vertically up towards the center of the lumbar support feature. The edge of the lumbar support height was also measured from the seat pan and vertically up to the inferior edge of the lumbar support feature. Lumbar support point was the vertical point from the lumbar support cushion to the seat pan. Lumbar support point was only recorded once the participant got off the seat. Backrest point was the vertical point from the backrest cushion to the seat pan. This was also only measured once the participant got off the seat pan. The difference between lumbar support point and backrest point determined the cushion depth for the backrest of the chair.

Figure 9. Backrest height and lumbar support height measurement.

ARMREST MEASUREMENTS

Armrest height and armrest length was taken while the participant kept their elbow at 90^0. The armrest height/Elbow height measurement was taken with a plastic ruler, measuring the distance vertically, from the seat pan to the middle of the lower arm. Armrest length/ Arm length was the measurement of the arm from the elbow to the wrist. Distance between the armrests was the same measure taken for seat width.

PARTICIPANT CHARACTERISTICS

SAMPLE

Companies were selected from many cities and towns in South Africa to ensure reliability and validity within the sample, to accurately represent South African anthropometric dimensions. Only South African citizens participated in this research. Companies were selected in Johannesburg, Pietermaritzburg, Durban, East London, Grahamstown, Uitenhage and Cape Town. Companies included in this study were: CSIR, Tata Motors and Tom Campher Motors (Pty)Ltd - Volvo Cars; Sappi Forests, NCT Forestry, Mondi and ICFR; Feltex Automotive and a number of sectors in Transnet; Johnson and Johnson (Pty) Ltd and I.C. Clark Inc.; Carara Agro Processing, Volkswagen; and Clicks Group Limited.

The sample for the study included 683 South African participants. The age range was 18 to 65 years; this incorporates the adult working population. All ethnic groups (Black, White, Coloured and Indian/Asian) were included in this study, in order to obtain most accurate population characteristics. A large sample was selected to ensure a reliable and valid representation of the South African population. A larger percentage of White, Coloured and Indian/Asian were collected in order for reliable and accurate measures to be obtained.

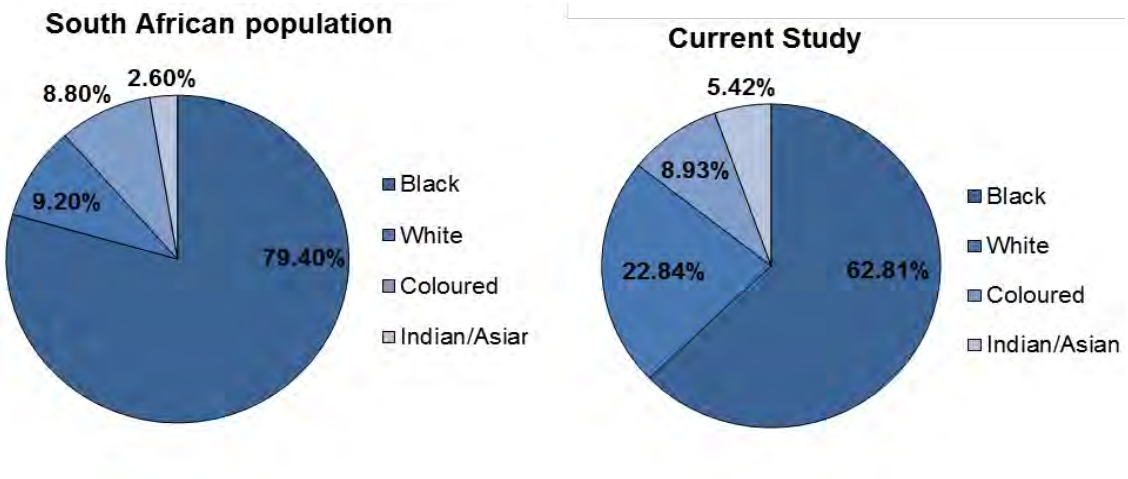

Figure 10. Included percentages (%) of the South African ethnic groups (Left - South African population, taken from Lehohla, 2010. Right - Current study population).

The Black ethnic group made up the largest percentage in the current study (62.81%) and in the South African population at large (79.40%). The White ethnic group had a population of 9.20% and the study represented a larger percentage (22.84%). The current study mirrored the Coloured ethnic group percentage (8.93%) most accurately to the overall South African Coloured population percentage (8.80%). The Indian/Asian ethnic group represented the smallest population percentage relative to the South African population (2.60%) and for the current study (5.42%). Chair dimensions were calculated according to the ethnic groups (in order to fit the 5th%ile and 95th%ile individually). The difference between the sample and population distribution did not affect the representation of the study but may affect the precision of the data.

The participants included office workers and also factory and forestry workers who were not office-bound. The exclusion criteria for the research were that the participants should not have any musculoskeletal injuries or deformities as this would have resulted in incorrect positioning of the chair structures, and that female participants were not pregnant as this would have given inaccurate anthropometric measurements such as body mass index (BMI) and waist to hip ratio (WHR) which indicate fat deposits and obesity (Kroemer, 2006). No other exclusion criteria were applied in order to consider the extreme ends of the distribution.

HUMAN MEASUREMENTS

Aside from the chair parameters the following body measurements were taken for each participating individual. All measurements were obtained by the principal researcher for reliability and validity.

According to ISO 7250 (2008), stature is the vertical height from the floor to the vertex and it is measured with an anthropometer. When measuring stature, the participant stands completely erect with their feet together and head in the Frankfurt plane. Stature (mm) was taken with a standard 1.5m dressmaker's tape measure that was fixed on the wall one meter from the floor. Participants were asked to remove shoes, and to stand with heels together and against the wall, buttocks and posterior aspect of the head touching the wall and to look straight ahead while the measure was taken. Participants removed their shoes as this is the standard procedure when measuring stature and therefore other studies can compare the values obtained in this study to the sample within their study. Stature was measured from the floor to the highest point, the apex of the skull (see figure 11, A). A ruler was placed flat and horizontally on the participants head to indicate the exact point on the tape measure, attached to the wall.

Shoulder height (mm) was taken in the same manner as stature was recorded, however, with a metal adjustable ruler, and was recorded as the distance between the floor and the acromion process (see figure 11, A).

Body mass is the total weight of the body and the participant stands on a weighing scale (ISO 7250, 2008). Body mass (kg) was recorded to the nearest 0.5kg on a commercially available bathroom scale, following removal of shoes, coats, jackets and any other heavy items of clothing on the person.

According to ISO 7250 (2008), waist circumference is measurement of the participant's trunk at a level midway at the lowest ribs and the upper iliac crest. The participant stands erect and relaxes the abdominal muscles. Waist circumference (mm) and hip circumference (mm) were recorded using a standard 1.5m dressmaker's tape measure. Waist circumference was taken just above the hip bone,

around the abdomen at the level of the umbilicus, and hip circumference was taken around the largest area of the hips and buttocks as viewed from the side. For these measurements participants were required to stand with their feet together and arms stretched out in the sagittal plane (see figure 11, B)

.

Stature and mass were recorded in order for a Body Mass Index (BMI) and Waist to Hip ratio (WHR) to be calculated.

BMI: [mass (kg).stature (m^{-2})] according to Keys *et al.* (1972).

WHR: [waist (mm) / hip (mm)] according to WHO (2008).

A **B**

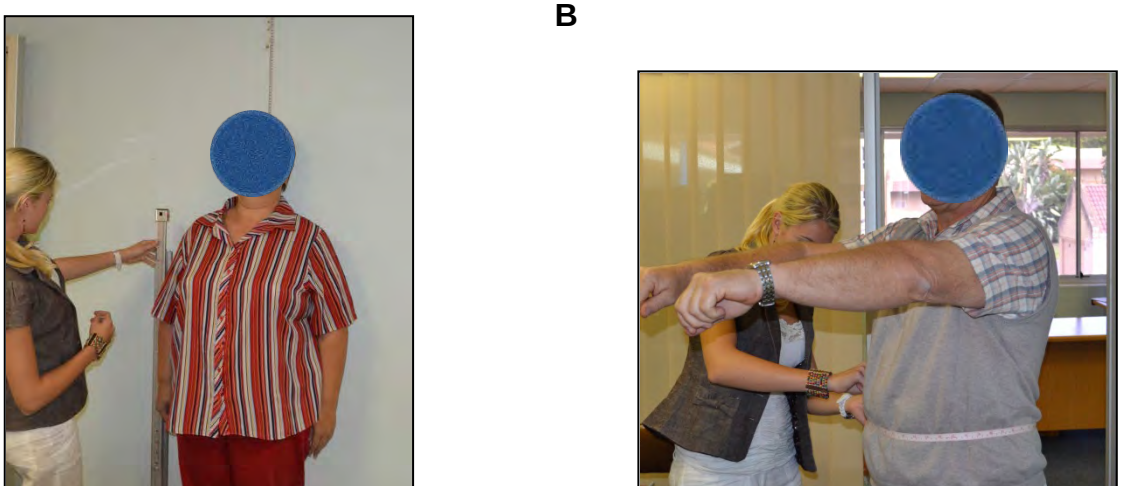

Figure 11. Anthropometric measurements. A: Stature and shoulder height. B: Waist and hip circumference.

PILOT STUDY

A preliminary study was conducted in and around Grahamstown, prior to the main experiment process. Ten participants (nine females and a male) participated in the pilot testing. The main purpose of the pre-test was to ensure that the researcher performed accurate anthropometric chair measurements and it also indicated the duration that the participants would be needed for the testing procedure.

The data collected during the pilot phase facilitated the design of an “in-house”, fully adjustable anthropometric measuring chair. This chair was later used for all data collection, and facilitated accurate measurement of all participants in the study.

ETHICS

Ethical approval was obtained from the Human Kinetics and Ergonomics departmental ethics committee for research involving human participants. All the participants were informed of the nature of the study by means of both a written (Appendix A1) and verbal explanation and then the participants signed an informed consent (Appendix A2) form.

EXPRIMENTAL PROCEDURE

PROCEDURE

The experimental sessions were conducted at times convenient to the researcher and the participant. On arrival, the testing procedure was explained in detail, both verbally and in writing (Appendix A1). Questions were addressed and the participants signed the consent form (Appendix A2). Language barriers due to varying home languages spoken by the participants were managed by a supervisor or a co-worker within the company, who translated the information to the participant's home language. The supervisor or co-worker of the company was present during the testing procedure to ensure the participant had a clear understanding of the procedure.

PARTICIPANT MEASUREMENTS

After completing the introduction, the participant's personal information (age, gender, home language and ethnic group) were recorded and then the participant's stature, shoulder height, body mass, hip and waist circumference were recorded (Appendix B1). The duration of the participant measurements was not longer than about 5 minutes.

A dressmaker's tape measure was placed on a wall at 1 meter above the floor. The participant stood with his/her back and heels against the wall. Shoulders were relaxed, legs close together and head faced forward. Once the correct position was attained, stature and shoulder height were recorded. The participant then stood on a scale and body mass was recorded. BMI could then be calculated.

The participant maintained this position, but further away from the wall, when waist and hip circumferences were measured. The waist and hip circumferences were measured with a dressmaker's tape measure. Waist circumference was measured around the largest part of the abdomen, just above the umbilicus, and hip circumference was taken around the largest part of the buttocks. This allowed for the waist-to-hip ratio to be calculated.

CHAIR CHARACTERISTICS

Once the participant measures were completed, the chair measurements were recorded. These measurements were recorded while the participant was seated on the measuring chair. Before being seated on the chair, the seat height had to be adjusted to fit the participant's leg length. This involved increasing or decreasing the seat height so that the knees could be bent at 90^0 while seated, so that the thigh was horizontal. The participant was required to position himself/herself in the center of the chair with his/her popliteal against the anterior aspect of the seat pan.

Once the participant was seated, the backrest and the lumbar support features were adjusted to fit the participant and create a comfortable and correct sitting posture. The backrest was placed over the scapula and the lumbar support was placed where a belt would normally be positioned around the waist (Simons et al., 1999) or 8 to 10 inches above the seat pan (Grew-Sheridan and Grew-Sheridan, 1995). The lumbar support for this study was therefore placed between the 2^{nd} and 5^{th} vertebrae.

The participant was seated upright, feet hip distance apart and flat on the ground, knees at 90º angles, upper arms relaxed at the side and elbows at 90º, head upright and eyes looking straight ahead. The duration of the measuring process was not longer than five minutes. The anthropometric measurements taken included seat pan measurements, backrest and lumbar support measurements and armrest measurements.

STATISTICAL ANALYSIS

Microsoft® Excel 2010 and STATISTICA (version 10) were used to calculate means, standard deviations, coefficient of variations, percentiles, significant correlations and graphical representations (figures and tables). The 5^{th} and 95^{th} percentiles for the anthropometric dimensions were used to eliminate the extreme outliers such that it does not distort the results.

CHAPTER IV

RESULTS

INTRODUCTION

A number of anthropometric office chair measurements were taken from the South African population, including seat height (mm), seat width (mm), seat depth anterior (mm), seat depth posterior (mm), backrest height (mm), backrest width (mm), lumbar support height (mm), armrest height and length (mm), backrest point (mm), lumbar support point (mm), cushion depth (mm) and thigh height (mm). Participant measurements were also recorded, including stature (mm), shoulder height (mm), mass (kg), body mass index (BMI) ($kg.m^{-2}$), waist circumference (mm), hip circumference (mm) and waist and hip ratio (WHR). Personal information was also taken, including age (yrs), gender and ethnic group. Percentiles and significant differences were calculated for the total South African sample, gender and ethnic groups and are illustrated in tables below. A redesigned office chair was constructed by the Human Kinetics and Ergonomics department, according to the South African sample's anthropometric dimensions. This was compared to standard office chairs used in South Africa.

PARTICIPANT CHARACTERISTICS

A total of 683 participants comprised of South Africans made up the population for this study. The sample included the different ethnic groups in the South African population, namely the Black, White, Coloured and Indian/Asian racial groups.

Table III: Total sample characteristics (n=683).

	AGE (yrs.)	STATURE (mm)	SHOULDER HEIGHT (mm)	MASS (kg)	BMI ($kg.m^{-2}$)	WAIST CIRCUM. (mm)	HIP CIRCUM. (mm)	WHR
MEAN	38.2	1666	1354	79.7	28.9	955	1102	0.9
SD	11.3	97	79	19.6	7.1	161	146	0.1
CV (%)	29.7	6	6	24.5	24.7	17	13	11.2
95^{th}%ILE	58.0	1830	1500	115.0	41.9	1220	1369	1.0
50^{th}%ILE	36.0	1660	1350	77.0	28.0	960	1080	0.9
5^{th}%ILE	22.1	1520	1230	53.0	19.6	710	910	0.7
MAX	65.0	2040	1640	160.0	59.5	1800	1720	1.8
MIN	18.0	1450	1110	40.0	15.6	590	620	0.6

SD = standard deviation; CV = coefficient of variation; MAX = maximum; MIN = minimum; 95^{th}%ILE = upper 95^{th} percentile of the population; 50^{th}%ILE = half of the population; 5^{th}%ILE = lower 5^{th} percentile of the population; CIRCUM. = circumference.

The participants' age ranged between 18 and 65 years and the average stature was 1666±97mm. The average shoulder height was 1354±79mm. The average body mass and maximum body mass recordings were 79.7±19.6kg and 160kg respectively. The average BMI was 28.9±7.1$kg.m^{-2}$ and the maximum BMI was 59.5$kg.m^{-2}$. The average waist circumference was 955±161mm and hip circumference was 1102±146mm. The average WHR was 0.9±0.1 and the 95^{th}%ile was 1.0±0.1.

Table IV: Female sample characteristics (n=448).

	AGE (yrs.)	STATURE (mm)	SHOULDER HEIGHT (mm)	MASS (kg)	BMI ($kg.m^{-2}$)	WAIST CIRCUM. (mm)	HIP CIRCUM. (mm)	WHR
MEAN	36.2	1624	1319	78.3	29.7	953	1128	0.9
SD	10.6	71	60	20.4	7.6	166	155	0.1
CV	29.2	4	5	26.0	25.6	17	14	11.5
95TH%ILE	56.0	1740	1410	115.7	44.3	1230	1397	1.0
50TH%ILE	34.0	1620	1320	75.5	29.0	960	1110	0.8
5TH%ILE	22.0	1510	1220	50.0	19.6	700	920	0.7
MAX	65.0	1870	1490	149.0	56.6	1550	1720	1.8
MIN	18.0	1450	1110	40.0	15.6	590	620	0.6

SD = standard deviation; CV = coefficient of variation; MAX = maximum; MIN = minimum; 95^{th}%ILE = upper 95^{th} percentile of the population; 50^{th}%ILE = half of the population; 5^{th}%ILE = lower 5^{th} percentile of the population; CIRCUM = circumference.

The age range of the female sample was between 18 and 65 years. The average stature was 1624±71mm and shoulder height was 1319±60mm. The average mass was 78.3±20.4kg and BMI was 29.7±7.6$kg.m^{-2}$. The average waist and hip

circumference were 953±166mm and 1128±155mm respectively and the average WHR was 0.9±0.1.

Table V: Male sample characteristics (n= 235).

	AGE (yrs.)	STATURE (mm)	SHOULDER HEIGHT (mm)	MASS (kg)	BMI ($kg.m^{-2}$)	WAIST CIRCUM. (mm)	HIP CIRCUM. (mm)	WHR
MEAN	42.0	1745	1420	82.4	27.2	959	1052	0.9
SD	11.8	88	68	17.6	5.8	153	113	0.1
CV	28.0	5	5	21.4	21.3	16	11	9.1
95TH%ILE	59.0	1910	1536	114.0	36.5	1171	1220	1.0
50TH%ILE	43.0	1740	1410	82.0	26.8	960	1040	0.9
5TH%ILE	23.0	1610	1310	57.0	19.6	737	900	0.8
MAX	65.0	2040	1640	160.0	59.5	1800	1700	1.5
MIN	18.0	1540	1280	51.0	17.8	660	720	0.7

SD = standard deviation; CV = coefficient of variation; MAX = maximum; MIN = minimum; 95^{th}%ILE = upper 95^{th} percentile of the population; 50^{th}%ILE = half of the population; 5^{th}%ILE = lower 5^{th} percentile of the population; CIRCUM = circumference.

The male age range was also between 18 and 65 years. The average stature and shoulder height was 1745±88mm and 1420±68mm respectively. The average mass was 82.4±17.6kg and the average BMI was 27.2±5.8$kg.m^{-2}$. The average waist and hip circumference were 959±153mm and 1052±113mm respectively. The average WHR was 0.9±0.1.

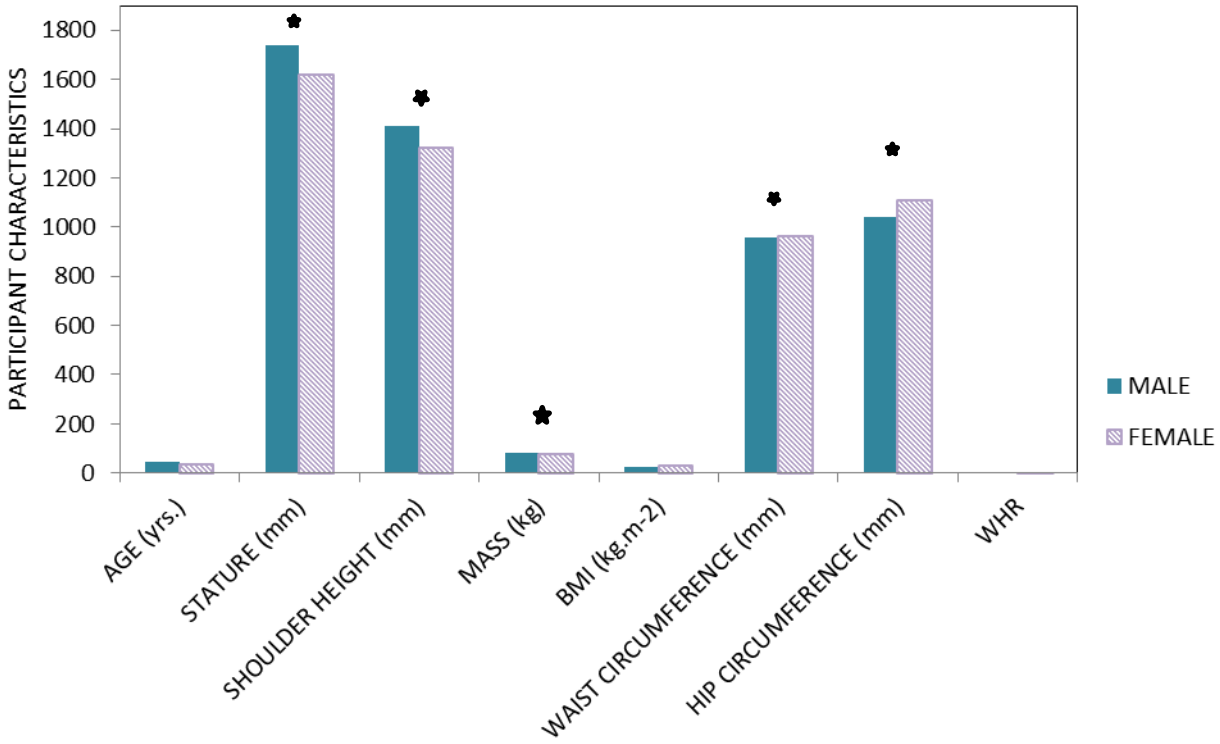

Figure 12. Comparison of male and female characteristics.

* indicates significant ($p<0.05$).

The significant difference ($p<0.05$) for male and female characteristics were found for stature, shoulder height, mass, BMI, waist circumference and hip circumference. The South African male sample had a greater stature, shoulder height and mass compared to the South African female sample.

ETHNIC AND SEX EFFECT ON PARTICIPANT MEASUREMENTS

STATURE

Stature was significantly ($p<0.01$) affected by both sex and ethnicity (see appendix C2).

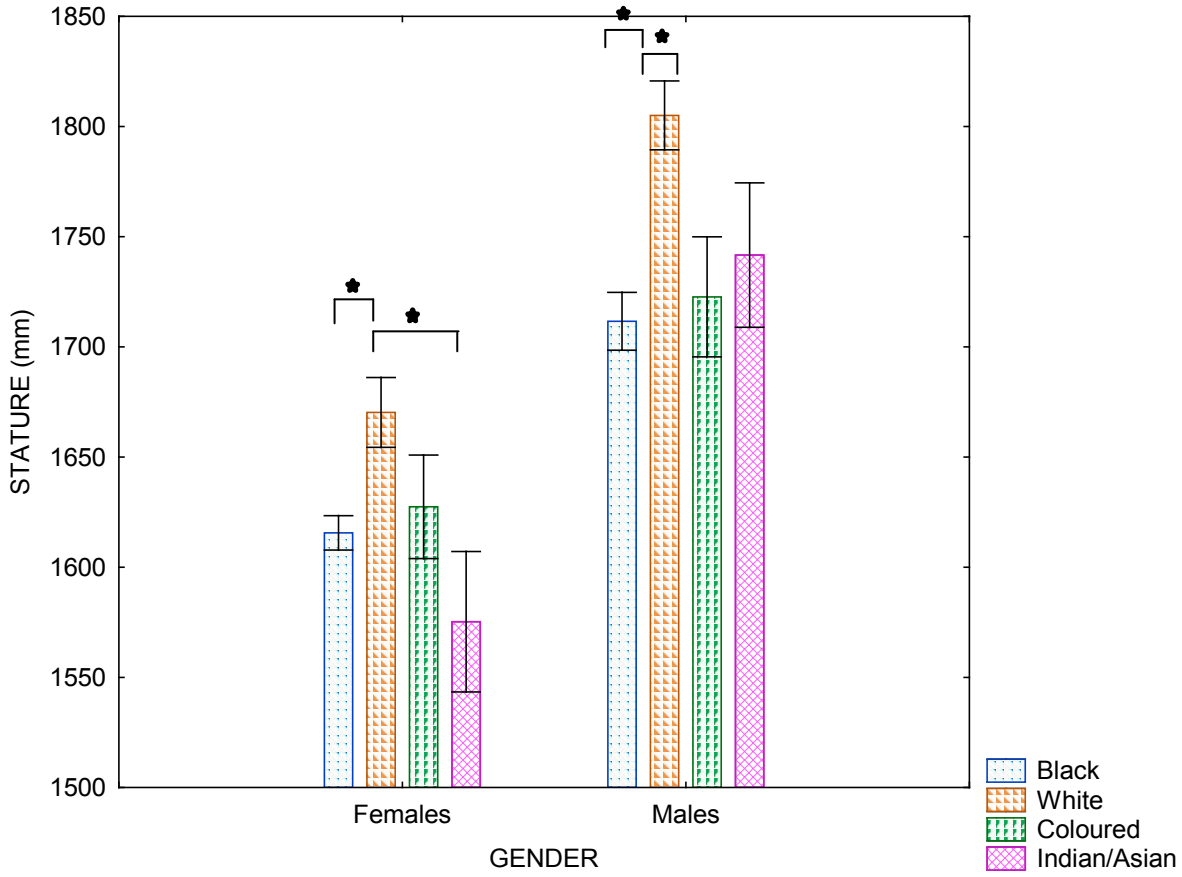

Figure 13. Stature considering 'Ethnic groups' and 'Gender'.

★ indicates significant difference ($p<0.01$).

The male group had a greater stature (1745±88mm) compared to the female group (1624±71mm). The White female group had a significantly greater ($p<0.01$) stature (1670±73mm) compared to the Black female stature (1615±68mm) and Indian/Asian female stature (1584±65mm). The White males had a significantly greater ($p<0.01$) stature (1805±75mm) compared to the Black male stature (1711±72mm) and Coloured male stature (1720±87mm). The White ethnic group had the tallest individuals within each gender group (see appendix C3).

SHOULDER HEIGHT

Sex and ethnicity had a significant impact on shoulder height ($p<0.05$; see appendix C2).

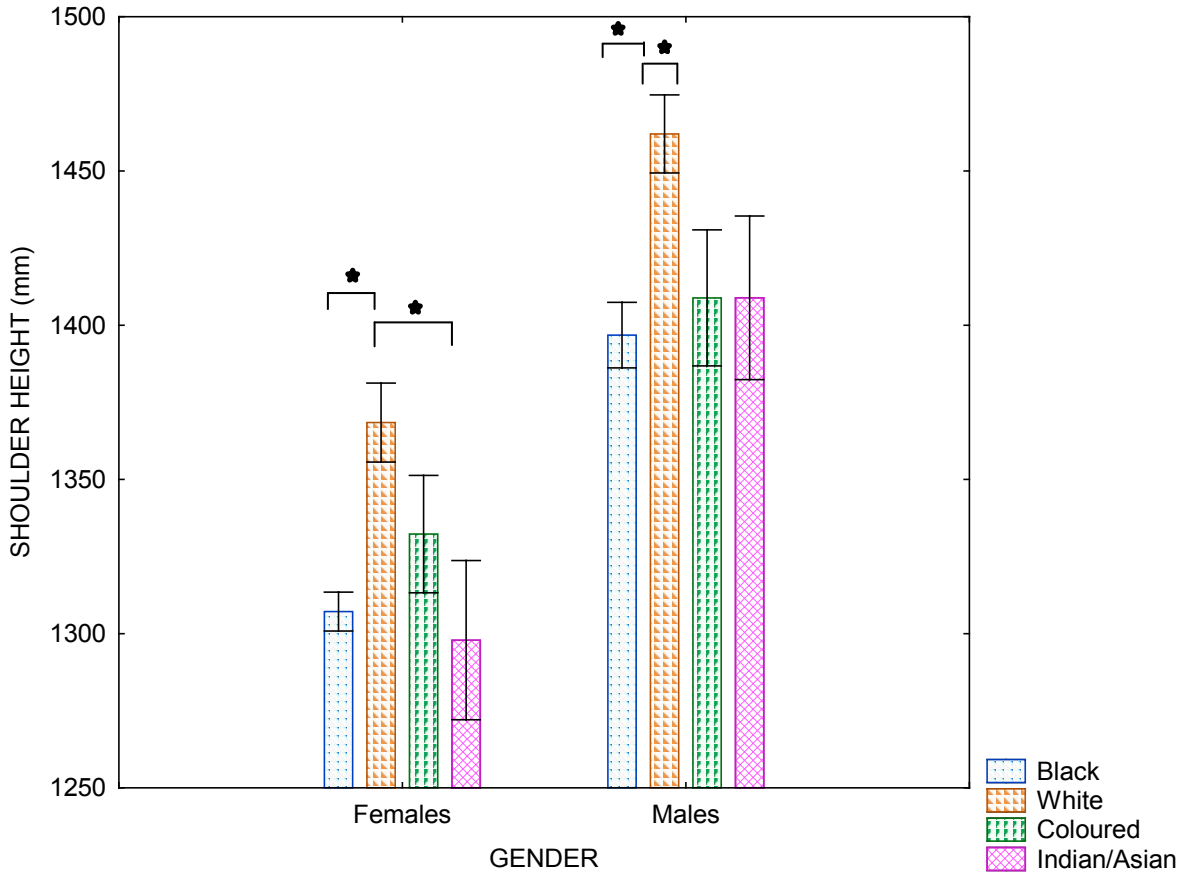

Figure 14. Shoulder Height considering 'Ethnic groups' and 'Gender'.

★ indicates significant difference ($p<0.05$).

The White female group had a significantly greater ($p<0.01$) shoulder height (1368±51mm) compared to the Black female shoulder height (1307±56mm) and Indian/Asian female shoulder height (1301±67mm). The White male group also had a significantly greater ($p<0.05$) shoulder height (1462±60mm) compared to the Black male shoulder height (1396±61mm) and Coloured male shoulder height (1410±60mm). The White ethnic group had the tallest individuals within each gender group. Similar trends occurred for stature (see appendix C3).

BODY MASS

Body mass differed significantly with sex ($p<0.01$) as well a significant impact between ethnic groups and body mass ($p<0.05$, see appendix C2).

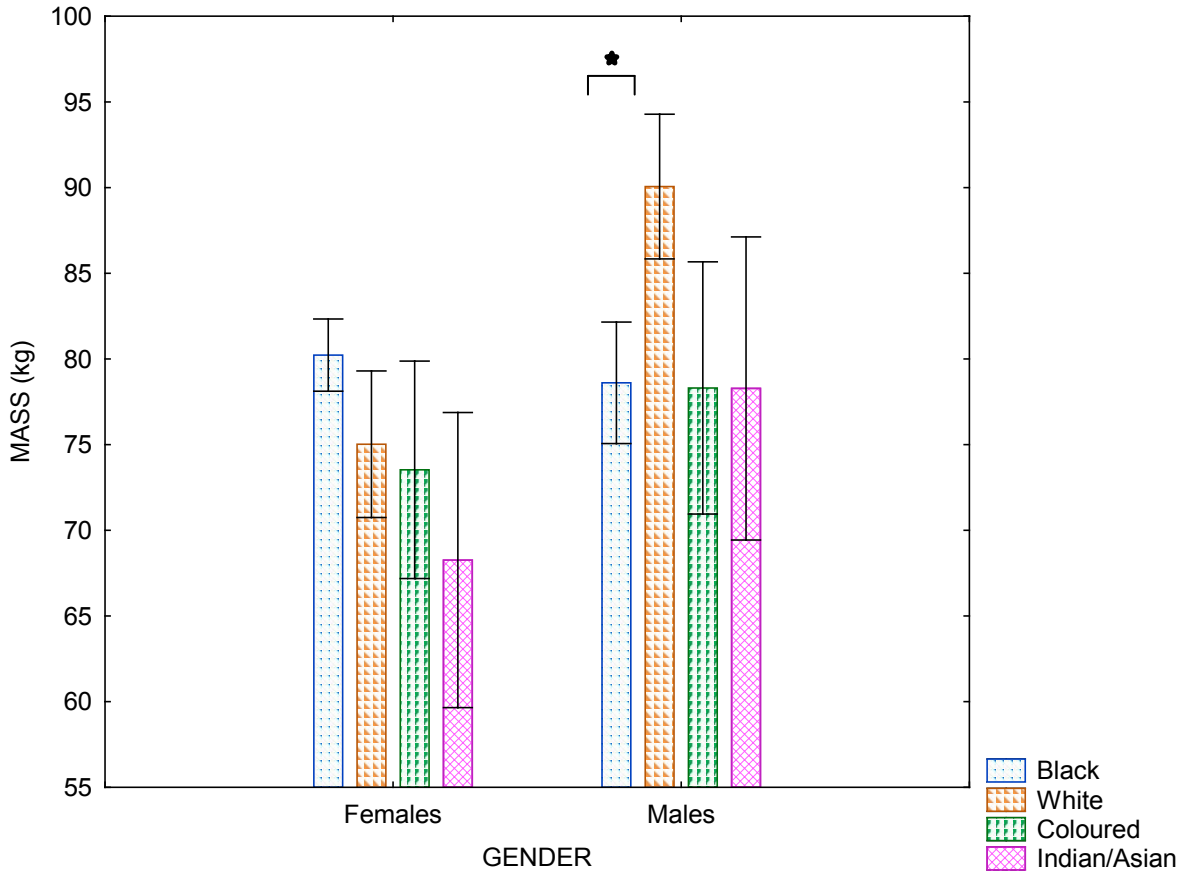

Figure 15. Body Mass considering 'Ethnic groups' and 'Gender'.

★ indicates significant difference ($p<0.05$).

No significant difference was observed within the female sample. Body mass varied however the greatest within the Indian/Asian female group. The Black female group had the greatest average body mass (80.0±20.1kg) for the female sample. A significant difference ($p<0.05$) was observed between the Black male body mass and White male body mass (difference of 10.8kg). The White males had the greatest body mass (90.0±15.9kg) within the male sample (see appendix C3).

BODY MASS INDEX

Ethnic groups had a significant impact on body mass index (BMI) ($p<0.01$; see appendix C2).

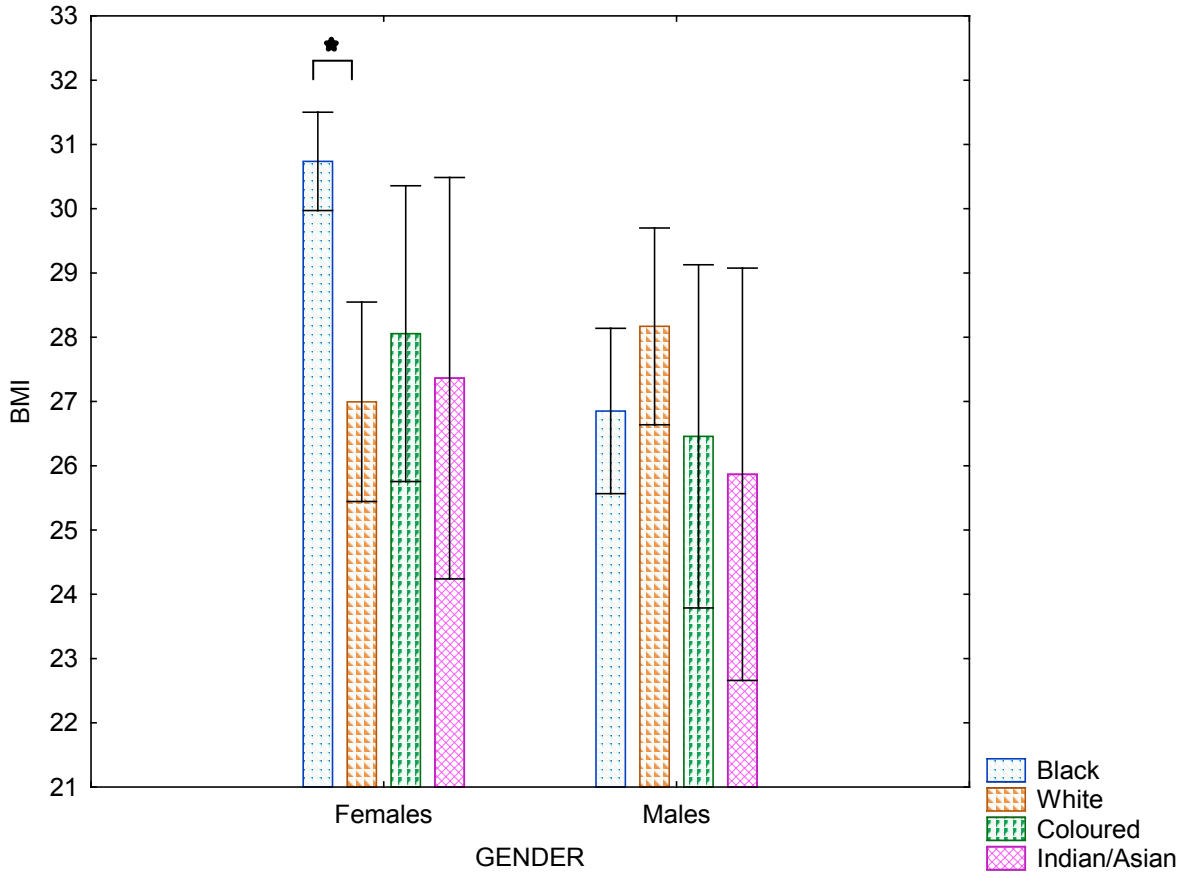

Figure 16: Body mass index considering 'Ethnic groups' and 'Gender'.

★ indicates significant difference ($p<0.05$).

Large variations were observed within gender groups. The Black females had the greatest BMI (30.7±7.4kg.m^{-2}) for the South African sample. The Black female group also had a significantly greater BMI compared to the White female group (27.0±7.4kg.m^{-2}) ($p<0.05$; see appendix C3).

WAIST CIRCUMFERENCE

Sex and ethnicity had a significant impact on waist circumference ($p<0.05$; see appendix C2).

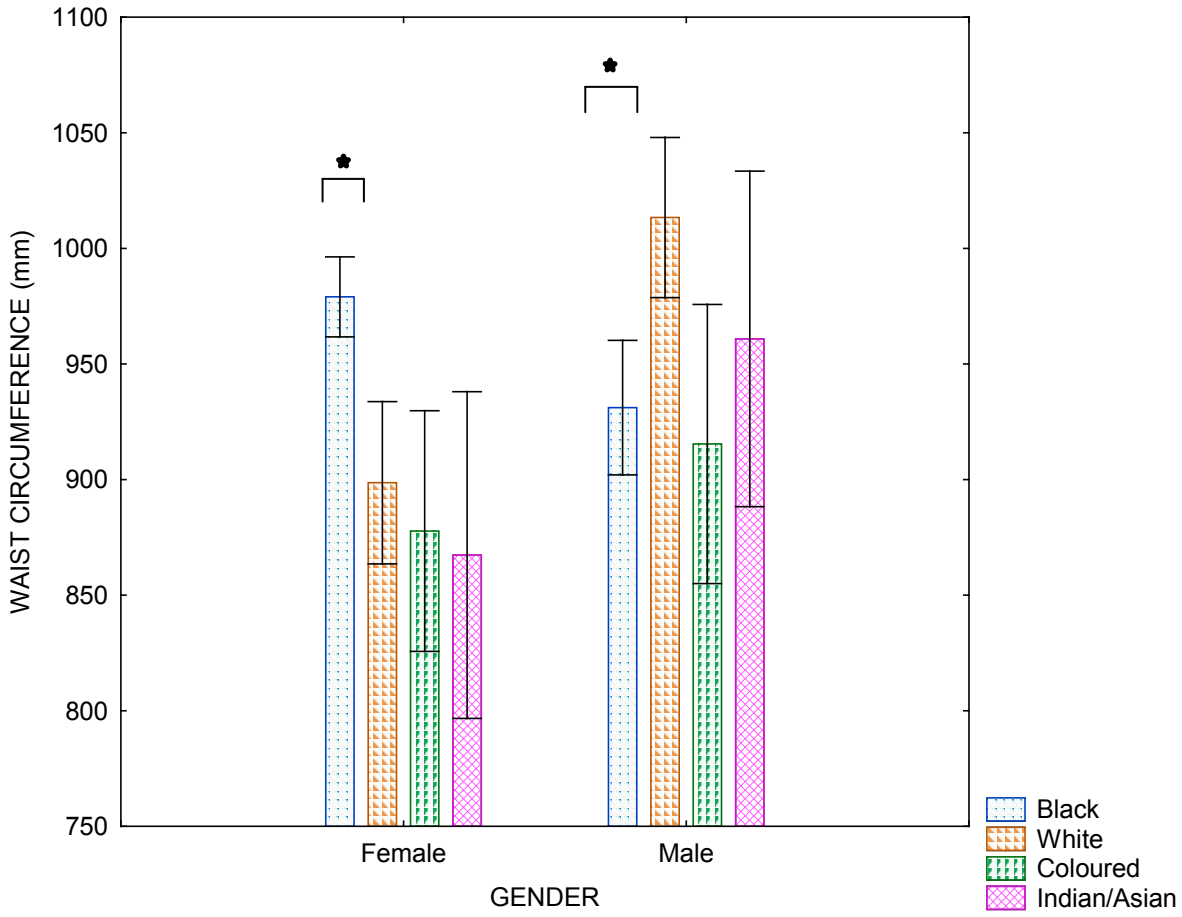

Figure 17: Waist Circumference considering 'Ethnic groups' and 'Gender'.

★ indicates significant difference ($p<0.05$).

The Black female group had a significantly greater ($p<0.05$) waist circumference (979±162mm) compared to the White female group (899±162mm). The White male group had a significantly greater ($p<0.05$) waist circumference (1013±153mm) compared to the Black males (931±152mm). The Black female group and the White male group had the greatest waist circumference within gender (see appendix C3).

HIP CIRCUMFERENCE

It was observed that there was a significant impact of sex on hip circumference ($p<0.01$). A significant impact of ethnic groups on hip circumference was observed ($p<0.05$), as well as a significant difference for the interaction of gender and ethnic groups on hip circumference ($p<0.01$; see appendix C2).

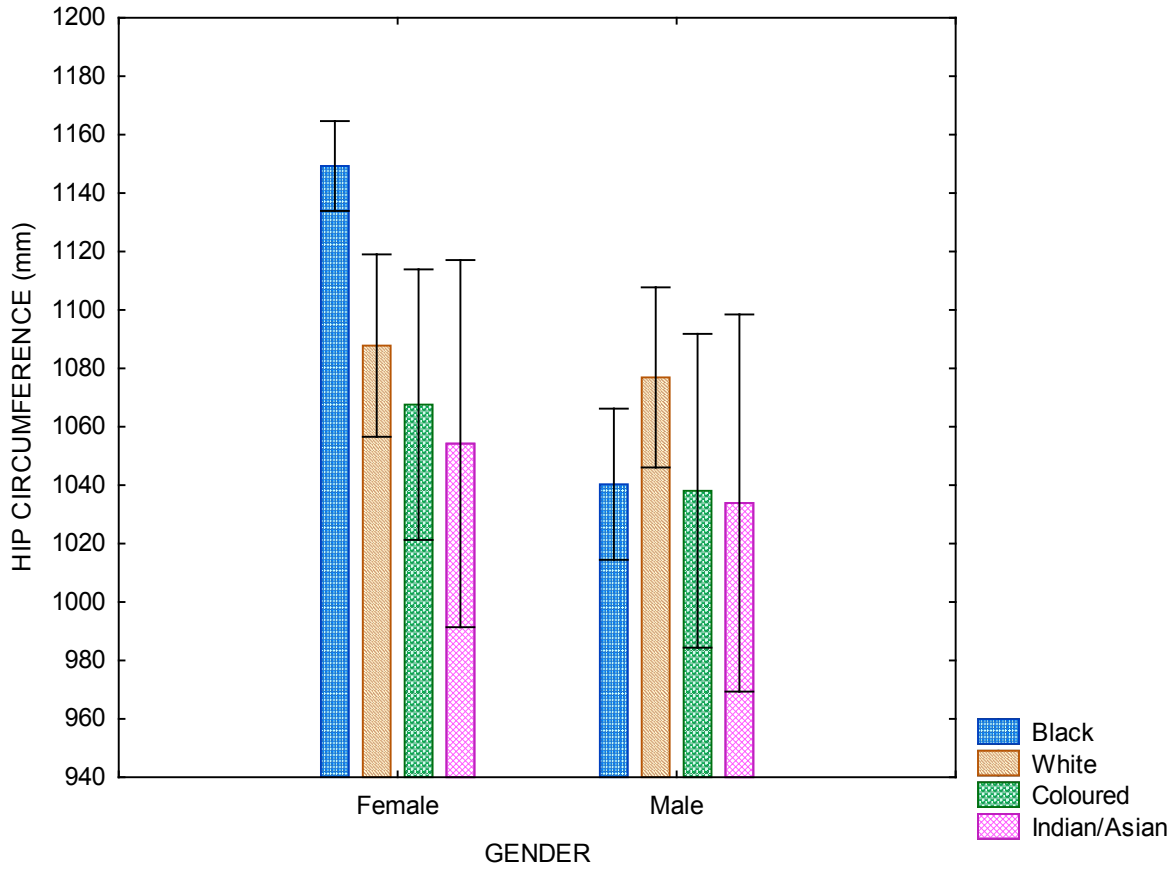

Figure 18: Hip Circumference considering 'Ethnic groups' and 'Gender'.

No significant differences were observed within gender groups. The Black female group had the largest hip circumference (1149±151mm) in the South African sample (see appendix C3).

WAIST TO HIP RATIO

A significant impact was observed for sex, ethnic groups and the interaction between sex and ethnic groups on waist-to-hip-circumference ($p<0.05$; see appendix C2).

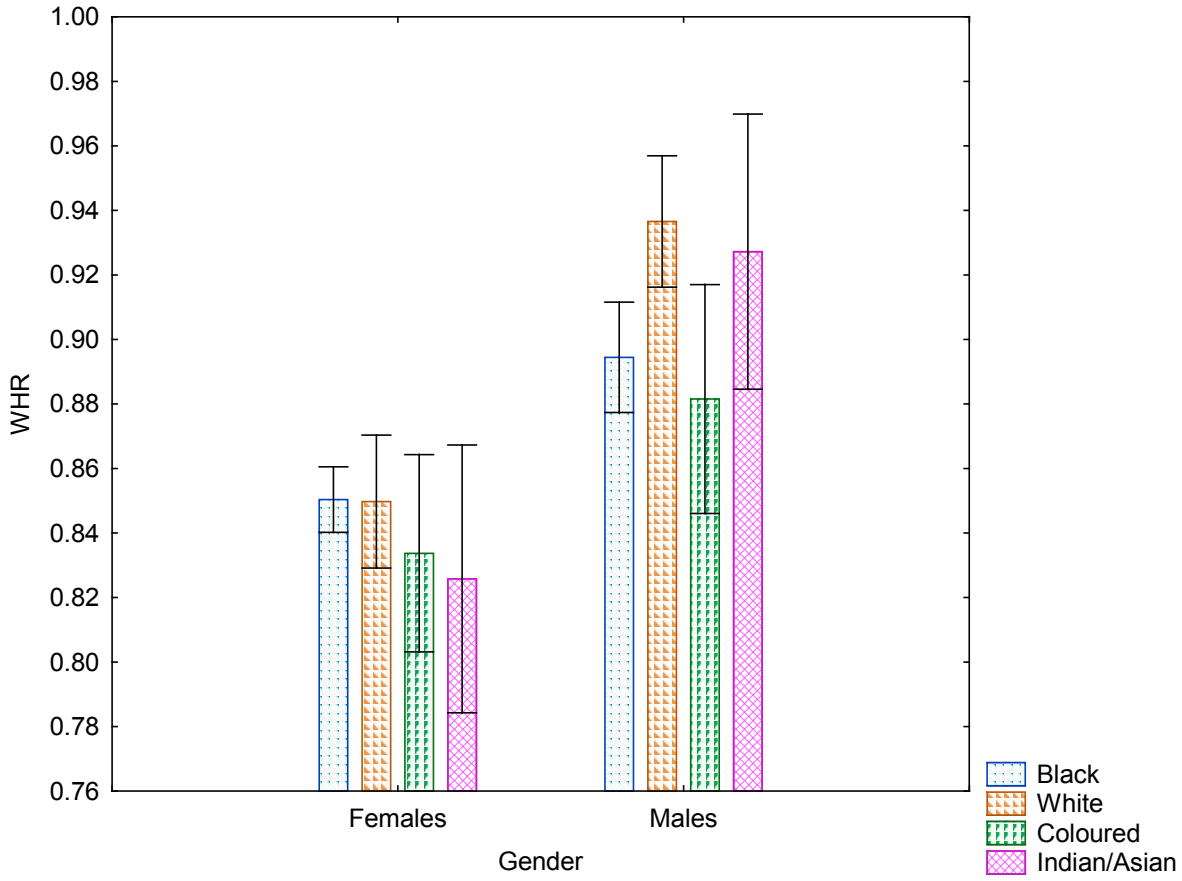

Figure 19: Waist to hip ratio considering 'Ethnic groups' and 'Gender'.

There were no significant differences observed within the gender groups. The 50th%ile for waist to hip ratio for the female sample was 0.8 and the waist to hip ratio for the male sample was 0.9 (see appendix C3).

CORRELATIONS FOR PARTICIPANT DIMENSIONS FOR THE SOUTH AFRICAN SAMPLE

Correlations were calculated to identify if any one variable could influence another. In turn one could assume the trends for future population dimensions.

Table VI: Correlations for participant dimensions (Marked correlations are significant, $p<0.05$).

	AGE	STATURE	SHOULDER HEIGHT	MASS	BMI	WAIT CIRCUM.	HIP CIRCUM.	WHR
AGE	1.00	**0.17**	**0.21**	**0.25**	**0.18**	**0.33**	**0.16**	**0.34**
STATURE	**0.17**	1.00	**0.93**	**0.30**	**-0.16**	**0.09**	-0.08	**0.22**
SHOULDER HEIGHT	**0.21**	**0.93**	1.00	**0.32**	**-0.11**	**0.12**	-0.05	**0.22**
MASS	**0.25**	**0.30**	**0.32**	1.00	**0.87**	**0.88**	**0.86**	**0.29**
BMI	**0.18**	**-0.16**	**-0.11**	**0.87**	1.00	**0.85**	**0.91**	**0.19**
WAIT CIRCUM.	**0.33**	**0.09**	**0.12**	**0.88**	**0.85**	1.00	**0.84**	**0.50**
HIP CIRCUM.	**0.16**	-0.08	-0.05	**0.86**	**0.91**	**0.84**	1.00	0.04
WHR	**0.34**	**0.22**	**0.22**	**0.29**	**0.19**	**0.50**	0.04	1.00

Circum. = circumference.

Age had a weak, positive, significant correlation between stature (0.17) and body mass (0.18). Stature had a strong, positive correlation between shoulder height (0.93) indicating that as stature increases so does shoulder height. Stature had a weak, negative correlation with BMI (-0.16), this indicates that as stature increases, BMI decreases therefore the taller individuals will have a smaller BMI value. Body mass had a strong, positive correlation with BMI (0.87), waist circumference (0.88) and hip circumference (0.86). BIM had a strong, positive correlation with waist circumference (0.85) and hip circumference (0.91) and waist circumference had a strong, positive correlation with WHR (0.50).

ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS

Anthropometric chair dimensions were recorded while the participant was seated on the anthropometric measuring chair. The chair dimensions included seat height, seat depth, seat width, backrest height, backrest width, armrest height and length, lumbar support height and edge of lumbar support height. Tables below represent office chair dimensions for the total South African sample, gender and each ethnic group.

Table VII: Total sample anthropometric office chair dimensions (n=683).

	MEAN	SD	CV	95TH%ile	50TH%ile	5TH%ile	MAX	MIN
SEAT HEIGHT (mm)	410	35	9	470	410	360	520	295
SEAT DEPTH ANTERIOR (mm)	514	32	6	570	510	460	610	400
SEAT DEPTH POSTERIOR (mm)	35	16	47	70	30	10	100	0
SEAT WIDTH (mm)	469	57	12	560	460	380	660	260
BACKREST HEIGHT (mm)	478	40	8	550	470	420	610	340
BACKREST WIDTH (mm)	469	58	12	560	460	380	660	205
ARMREST HEIGHT (mm)	189	29	15	235	190	145	350	110
ARMREST LENGTH (mm)	248	20	8	280	250	220	310	50
LUMBAR SUPPORT HEIGHT (mm)	192	31	16	250	190	150	280	120
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	162	31	19	220	160	120	250	90
THIGH HEIGHT (mm)	137	25	18	180	135	100	290	90
BACKREST POINT (mm)	576	33	6	630	580	520	650	420
LUMBAR SUPPORT POINT (mm)	514	33	6	570	510	460	610	400
CUSHION DEPTH (mm)	63	19	30	90	60	40	130	-20

SD = standard deviation; CV = coefficient of variation; 95th %ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum

Table VII indicates the anthropometric office chair dimensions for the total South African sample (n=683). The 95th%ile for seat height was 470mm and the 5th%ile was 360mm. Seat depths anterior indicated 570mm, 510mm and 460mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 70mm. Seat width indicated 560mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 550mm and 470mm and backrest width had a 5th%ile of 380mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 250mm, 150mm and 220mm, 120mm respectively. The 50th%ile for backrest point and lumbar support point were 580mm and 510mm respectively. The 50th%ile for cushion depth was 60mm.

The 50th%ile armrest height and armrest length were 190mm and 250mm respectively. The 95th%ile for armrest height was 235mm and the 5th%ile was 145mm. The average thigh height was 137±25mm, the 95th%ile was 180mm and the 5th%ile was 100mm.

FEMALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS

Table VIII: Total female anthropometric office chair dimensions (n=448).

	MEAN	SD	CV	95TH%ile	50TH%ile	5TH%ile	MAX	MIN
SEAT HEIGHT (mm)	394	28	7	447	390	350	520	295
SEAT DEPTH ANTERIOR (mm)	510	30	6	560	510	460	600	400
SEAT DEPTH POSTERIOR (mm)	400	16	41	70	40	20	90	0
SEAT WIDTH (mm)	480	60	12	580	480	380	660	260
BACKREST HEIGHT (mm)	468	34	7	527	470	420	580	340
BACKREST WIDTH (mm)	480	60	12	580	480	380	660	260
ARMREST HEIGHT (mm)	191	27	14	234	190	150	320	110
ARMREST LENGTH (mm)	248	10	4	270	240	220	2440	140
LUMBAR SUPPORT HEIGHT (mm)	201	32	16	260	200	150	280	120
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	171	32	19	230	170	120	250	90
THIGH HEIGHT (mm)	139	27	19	185	140	100	290	90
BACKREST POINT (mm)	575	32	6	620	580	520	650	460
LUMBAR SUPPORT POINT (mm)	510	30	6	560	510	460	600	400
CUSHION DEPTH (mm)	65	18	27	97	60	40	120	-20

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum

The anthropometric office chair dimensions for the total female sample are indicated in Table VIII. The 95th%ile for seat height was 447mm and the 5th%ile was 350mm. Seat depths anterior indicated 560mm, 510mm and 460mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 70mm. Seat width indicated 580mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 527mm and 420mm and backrest width had a 5th%ile of 380mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 260mm, 150mm and 230mm, 120mm respectively.

The 50th%ile for backrest point and lumbar support point were 580mm and 510mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height was 191±27mm, the 95th%ile was 234mm and the 5th%ile was 150mm. The average armrest length was 248±105mm and the 50th%ile was 240mm. The average thigh height was 139±27mm, the 95th%ile was 185mm and the 5th%ile was 100mm.

MALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS

Table IX: Total male anthropometric office chair dimensions (n=235).

	MEAN	SD	CV	95TH%ile	50TH%ile	5TH%ile	MAX	MIN
SEAT HEIGHT (mm)	440	26	6	480	440	400	510	370
SEAT DEPTH ANTERIOR (mm)	522	35	7	573	520	460	610	420
SEAT DEPTH POSTERIOR (mm)	25	13	52	50	20	10	100	10
SEAT WIDTH (mm)	448	46	10	520	440	380	580	340
BACKREST HEIGHT (mm)	495	44	9	570	490	430	610	400
BACKREST WIDTH (mm)	447	48	11	520	440	374	580	205
ARMREST HEIGHT (mm)	186	31	17	240	185	140	350	120
ARMREST LENGTH (mm)	259	23	9	290	260	234	310	50
LUMBAR SUPPORT HEIGHT (mm)	176	23	13	220	170	140	260	120
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	146	23	16	190	140	110	230	90
THIGH HEIGHT (mm)	134	22	16	170	130	105	220	95
BACKREST POINT (mm)	580	35	6	630	580	528	650	420
LUMBAR SUPPORT POINT (mm)	522	35	7	580	520	460	610	420
CUSHION DEPTH (mm)	58	20	34	90	60	37	130	-20

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

Anthropometric office chair dimensions for the total male sample are represented in table IX above. The 95th%ile for seat height was 480mm and the 5th%ile was 400mm. Seat depths anterior indicated 573mm, 520mm and 460mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 50mm. Seat width indicated 520mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 570mm and 430mm and backrest width had a 5th%ile of 374mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 220mm, 140mm and 190mm, 110mm respectively.

The 50th%ile for backrest point and lumbar support point was 580mm and 520mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height for the total male sample was 186±31mm, the 95th%ile for armrest height was 240mm and the 5th%ile was 140mm. The average armrest length was 259±23mm and the 50th%ile for armrest length was 260mm. The average thigh height was 134±22mm, the 95th%ile was 170mm and the 5th%ile was 105mm.

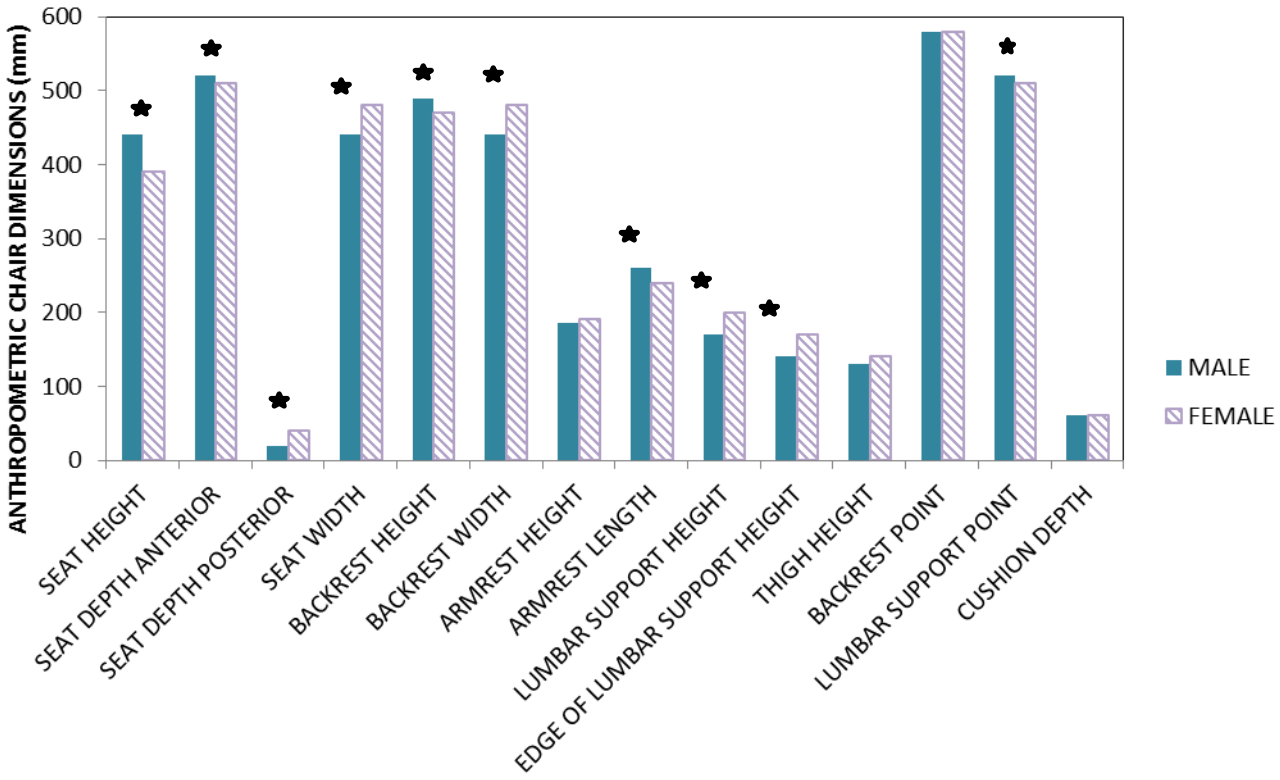

Figure 20: Comparison of male and female anthropometric chair dimensions.

* indicates significant difference ($p<0.05$).

The South African male sample had a significantly ($p<0.05$) greater seat height, seat depth anterior, backrest height and armrest height compared to the South African female sample. The South African female sample had a greater seat depth posterior, seat width, backrest width, lumbar support height, edge of lumbar support height and lumbar support point.

FEMALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: BLACK

Table X: Black female anthropometric office chair percentiles and dimensions (n=317).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	389	24	6	430	390	350	460	295
SEAT DEPTH ANTERIOR (mm)	513	30	6	560	510	470	600	400
SEAT DEPTH POSTERIOR (mm)	41	16	39	70	40	20	90	0
SEAT WIDTH (mm)	487	60	12	580	480	380	660	260
BACKREST HEIGHT (mm)	464	31	7	510	470	420	560	340
BACKREST WIDTH (mm)	487	60	12	580	480	380	660	260
ARMREST HEIGHT (mm)	188	26	14	230	190	149	320	110
ARMREST LENGTH (mm)	251	12	49	270	245	220	2440	205
LUMBAR SUPPORT HEIGHT (mm)	210	30	14	260	210	160	280	130
EDGE OF LUMBAR SUPPORT (mm)	180	30	16	230	180	130	250	100
THIGH HEIGHT (mm)	143	27	19	190	140	105	290	90
BACKREST POINT (mm)	581	29	5	620	580	540	650	470
LUMBAR SUPPORT POINT (mm)	514	30	6	560	510	470	600	400
CUSHION DEPTH (mm)	63	25	41	100	70	0	120	-40

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

Table X indicates the anthropometric office chair dimensions of the Black female sample. The 95th%ile for seat height was 430mm and the 5th%ile was 350mm. Seat depths anterior indicated 560mm, 510mm and 470mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 70mm. Seat width indicated 580mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 510mm and 420mm and backrest width had a 5th%ile of 380mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 260mm, 160mm and 230mm, 130mm respectively. The 50th%ile for backrest point and lumbar support point was 580mm and 510mm respectively. The 50th%ile for cushion depth was 70mm.

The average armrest height and armrest length were 188±26mm and 251±12mm respectively. The 95th%ile for armrest height was 230mm and the 5th%ile was 149mm and the 50th%ile for armrest length was 245mm. The average thigh height was 143±27mm, 95th%ile was 190mm and the 5th%ile was 105mm.

FEMALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: WHITE

Table XI: White female anthropometric office chair percentiles and dimensions (n=77).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	411	35	8	468	410	360	520	340
SEAT DEPTH ANTERIOR (mm)	506	28	6	550	510	460	570	460
SEAT DEPTH POSTERIOR (mm)	39	18	45	70	40	20	80	10
SEAT WIDTH (mm)	473	60	13	584	460	400	660	360
BACKREST HEIGHT (mm)	488	35	7	542	490	438	580	380
BACKREST WIDTH (mm)	473	60	13	584	460	400	660	360
ARMREST HEIGHT (mm)	200	25	13	240	200	160	270	150
ARMREST LENGTH (mm)	240	18	8	270	240	220	270	140
LUMBAR SUPPORT HEIGHT (mm)	187	24	13	222	185	150	250	120
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	157	24	15	192	155	120	220	90
THIGH HEIGHT (mm)	126	23	18	167	120	100	190	90
BACKREST POINT (mm)	565	3	6	610	570	520	630	500
LUMBAR SUPPORT POINT (mm)	506	28	6	550	510	460	570	460
CUSHION DEPTH (mm)	58	17	30	90	60	30	110	20

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

The White female anthropometric chair dimensions are indicated in table XI. The 95th%ile for seat height was 468mm and the 5th%ile was 360mm. Seat depths anterior indicated 550mm, 510mm and 460mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 70mm. Seat width indicated 584mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 542mm and 438mm and backrest width had a 5th%ile of 400mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 222mm, 150mm and 192mm, 120mm respectively. The 50th%ile for backrest point and lumbar support point was 570mm and 510mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height was 200±25mm, the 95th%ile was 240mm and the 5th%ile was 160mm. The average armrest length was 240±18mm and the 50th%ile for armrest length was 240mm. The average thigh height was 126±23mm, the 95th%ile was 167mm and the 5th%ile was 100mm.

FEMALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: COLOURED

Table XII: Coloured female anthropometric office chair percentiles and dimensions (n=35).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	398	30	8	443	400	354	460	330
SEAT DEPTH ANTERIOR (mm)	496	29	6	553	490	460	560	450
SEAT DEPTH POSTERIOR (mm)	34	15	45	60	30	10	70	10
SEAT WIDTH (mm)	455	43	10	520	460	380	540	360
BACKREST HEIGHT (mm)	474	39	8	550	470	427	580	420
BACKREST WIDTH (mm)	455	43	10	520	460	380	540	360
ARMREST HEIGHT (mm)	192	35	18	233	190	144	320	130
ARMREST LENGTH (mm)	237	16	7	260	235	212	280	200
LUMBAR SUPPORT HEIGHT (mm)	166	20	12	200	165	134	210	130
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	136	20	15	170	135	104	180	100
THIGH HEIGHT (mm)	139	28	20	194	130	105	215	100
BACKREST POINT (mm)	549	29	5	595	545	516	640	500
LUMBAR SUPPORT POINT (mm)	496	29	6	553	490	460	560	450
CUSHION DEPTH (mm)	57	15	26	80	60	36	100	30

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

Table XII indicates the anthropometric office chair dimensions for the Coloured female sample. The 95th%ile for seat height was 443mm and the 5th%ile was 354mm. Seat depths anterior indicated 553mm, 490mm and 460mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 60mm. Seat width indicated 520mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 550mm and 427mm and backrest width had a 5th%ile of 380mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 200mm, 134mm and 164mm, 75mm respectively. The 50th%iles for backrest point and lumbar support point were 545mm and 490mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height and armrest length was 192±35mm and 237±16mm respectively. The 95th%ile for armrest height was 233mm and the 5th%ile was 144mm and the 50th%ile for armrest length was 235mm. The average thigh height was 139±28mm, the 95th%ile was 194mm and the 5th%ile was 105mm.

FEMALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: INDIAN/ASIAN

Table XIII: Indian/Asian female anthropometric office chair percentiles and dimensions (n=19).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	393	42	11	447	380	330	510	330
SEAT DEPTH ANTERIOR (mm)	492	37	8	551	500	446	560	410
SEAT DEPTH POSTERIOR (mm)	35	15	44	52	30	19	70	10
SEAT WIDTH (mm)	449	65	14	562	440	338	580	320
BACKREST HEIGHT (mm)	453	34	8	504	450	418	540	400
BACKREST WIDTH (mm)	449	65	14	562	440	338	580	320
ARMREST HEIGHT (mm)	186	24	13	212	180	160	270	155
ARMREST LENGTH (mm)	237	18	8	270	230	215	270	210
LUMBAR SUPPORT HEIGHT (mm)	173	29	17	213	180	130	240	130
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	143	29	20	183	150	100	210	100
THIGH HEIGHT (mm)	124	22	18	160	120	90	160	90
BACKREST POINT (mm)	548	36	7	600	550	500	600	460
LUMBAR SUPPORT POINT (mm)	492	37	8	551	500	446	560	410
CUSHION DEPTH (mm)	61	17	28	90	60	40	90	40

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

Anthropometric office chair dimensions for the Indian/Asian female sample are represented in table XIII. The 95th%ile for seat height was 447mm and the 5th%ile was 330mm. Seat depths anterior indicated 551mm, 500mm and 446mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 52mm. Seat width indicated 562mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 504mm and 418mm and backrest width had a 5th%ile of 338mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 213mm, 130mm and 183mm, 100mm respectively. The 50th%iles for backrest point and lumbar support point were 550mm and 500mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height was 186±24mm and the average armrest length was 237±18mm. The 95th%ile for armrest height was 212mm; the 5th%ile was 160mm. The 50th%ile for armrest length was 230mm. The 95th%ile for thigh height was 160mm; the 5th%ile was 90mm.

MALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: BLACK

Table XIV: Black male anthropometric office chair percentiles and dimensions (n=112).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	436	28	6	480	430	390	500	370
SEAT DEPTH ANTERIOR (mm)	523	37	7	575	520	460	610	420
SEAT DEPTH POSTERIOR (mm)	26	14	54	50	20	10	100	10
SEAT WIDTH (mm)	435	49	11	520	430	360	580	340
BACKREST HEIGHT (mm)	479	40	8	550	470	430	600	400
BACKREST WIDTH (mm)	435	49	11	520	430	360	580	340
ARMREST HEIGHT (mm)	175	29	17	225	170	130	250	120
ARMREST LENGTH (mm)	260	27	10	300	260	233	310	50
LUMBAR SUPPORT HEIGHT (mm)	169	20	12	210	170	140	220	130
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	139	20	14	180	140	110	190	100
THIGH HEIGHT (mm)	134	24	18	175	130	100	220	95
BACKREST POINT (mm)	582	39	7	630	590	530	650	420
LUMBAR SUPPORT POINT (mm)	523	38	7	580	520	460	610	420
CUSHION DEPTH (mm)	63	22	35	110	60	40	130	10

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

Table XIV indicates the anthropometric office chair dimensions for the Black male sample. The 95th%ile for seat height was 480mm and the 5th%ile was 390mm. Seat depths anterior indicated 575mm, 520mm and 460mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 50mm. Seat width indicated 520mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 550mm and 430mm and backrest width had a 5th%ile of 360mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 210mm, 140mm and 180mm, 110mm respectively. The 50th%iles for backrest point and lumbar support point were 590mm and 520mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height was 175±29mm, the 95th%ile was 225mm and the 5th%ile was 130mm. The average armrest length was 260±27mm; the 50th%ile was 260mm. The 95th%ile for thigh height was 175mm and the 5th%ile was 100mm.

MALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: WHITE

Table XV: White male anthropometric office chair percentiles and dimensions (n=79).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	450	20	5	480	450	410	510	400
SEAT DEPTH ANTERIOR (mm)	520	30	6	570	530	470	610	450
SEAT DEPTH POSTERIOR (mm)	20	10	45	50	20	10	60	10
SEAT WIDTH (mm)	470	40	8	520	460	420	580	380
BACKREST HEIGHT (mm)	530	40	7	580	520	480	610	420
BACKREST WIDTH (mm)	470	40	8	520	460	420	580	380
ARMREST HEIGHT (mm)	200	30	14	250	200	160	350	150
ARMREST LENGTH (mm)	262	15	6	290	260	240	300	230
LUMBAR SUPPORT HEIGHT (mm)	176	23	13	220	170	140	260	120
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	146	23	16	190	140	110	230	90
THIGH HEIGHT (mm)	132	20	15	161	130	109	220	100
BACKREST POINT (mm)	580	30	5	630	590	530	650	510
LUMBAR SUPPORT POINT (mm)	530	30	6	570	530	470	610	450
CUSHION DEPTH (mm)	57	17	29	83	60	38	100	10

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

The White male anthropometric office chair dimensions are indicated in table XV above. The 95th%ile for seat height was 480mm and the 5th%ile was 410mm. Seat depths anterior indicated 570mm, 530mm and 470mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 50mm. Seat width indicated 520mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 580mm and 480mm and backrest width had a 5th%ile of 420mm. The 95th%ile and 5th%ile for lumbar support height

and edge of lumbar support were 220mm, 140mm and 190mm, 110mm respectively. The 50th%iles for backrest point and lumbar support point were 590mm and 530mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height and armrest length were 200±30mm and 262±15mm respectively. The 95th%ile for armrest height was 250mm and the 5th%ile is 160mm and the 50th%ile for armrest length was 260mm. The average thigh height was 132±20mm. The 95th%ile for thigh height was 161mm and the 5th%ile was 109mm.

MALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: COLOURED

Table XVI: Coloured male anthropometric office chair percentiles and dimensions (n=26).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	435	25	6	485	430	403	500	400
SEAT DEPTH ANTERIOR (mm)	513	38	7	578	510	450	590	440
SEAT DEPTH POSTERIOR (mm)	23	12	52	40	20	10	50	10
SEAT WIDTH (mm)	441	42	9	515	440	370	540	360
BACKREST HEIGHT (mm)	473	33	7	528	470	415	540	410
BACKREST WIDTH (mm)	433	62	14	515	440	360	540	205
ARMREST HEIGHT (mm)	187	36	19	240	180	146	300	140
ARMREST LENGTH (mm)	249	25	10	280	250	230	295	150
LUMBAR SUPPORT HEIGHT (mm)	167	22	13	208	160	135	215	120
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	137	22	16	178	130	105	185	90
THIGH HEIGHT (mm)	141	19	13	168	138	120	185	110
BACKREST POINT (mm)	560	30	6	610	560	510	630	500
LUMBAR SUPPORT POINT (mm)	510	40	7	580	510	450	590	440
CUSHION DEPTH (mm)	53	18	33	80	50	37	80	10

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

Table XVI indicates the anthropometric office chair dimensions for the Coloured male sample. The 95th%ile for seat height was 485mm and the 5th%ile was 403mm. Seat depths anterior indicated 578mm, 510mm and 450mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 40mm. Seat width indicated 515mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 528mm and 415mm and backrest width had a 5th%ile of 360mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 208mm, 135mm and 178mm, 105mm respectively. The 50th%ile for backrest point and lumbar support point were 560mm and 510mm respectively. The 50th%ile for cushion depth was 50mm.

The average armrest height and armrest length were 187±36mm and 249±25mm respectively. The 95th%ile for armrest height was 240mm, the 5th%ile was 146mm and the 50th%ile for armrest length was 250mm. The average thigh height was 141±19mm, the 95th%ile for thigh height was 168mm and the 5th%ile was 120mm.

MALE POPULATION ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR ETHNIC GROUP: INDIAN/ASIAN

Table XVII: Indian/Asian male anthropometric office chair percentiles and dimensions (n=18).

	MEAN	SD	CV	95TH%ILE	50TH%ILE	5TH%ILE	MAX	MIN
SEAT HEIGHT (mm)	434	24	6	470	435	389	470	380
SEAT DEPTH ANTERIOR (mm)	518	31	6	565	510	479	590	470
SEAT DEPTH POSTERIOR (mm)	30	12	40	50	30	10	50	10
SEAT WIDTH (mm)	457	35	8	500	470	400	500	400
BACKREST HEIGHT (mm)	496	41	8	555	480	449	580	440
BACKREST WIDTH (mm)	457	35	8	500	470	400	500	400
ARMREST HEIGHT (mm)	182	18	10	212	180	160	220	160
ARMREST LENGTH (mm)	257	16	6	281	258	234	285	230
LUMBAR SUPPORT HEIGHT (mm)	179	16	9	201	180	157	205	140
EDGE OF LUMBAR SUPPORT HEIGHT (mm)	149	16	11	171	150	127	175	110
THIGH HEIGHT (mm)	127	16	12	156	125	109	160	105
BACKREST POINT (mm)	573	32	6	622	575	530	630	530
LUMBAR SUPPORT POINT (mm)	518	31	6	565	510	479	590	470
CUSHION DEPTH (mm)	55	14	25	80	60	39	80	30

SD = standard deviation; CV = coefficient of variation; 95th%ILE = upper 95th percentile of the population; 50th%ILE = half of the population; 5th%ILE = lower 5th percentile of the population; MAX = maximum; MIN = minimum.

The office chair dimensions for the Indian/Asian male sample are represented in Table XVII. The 95th%ile for seat height was 470mm and the 5th%ile was 389mm. Seat depths anterior indicated 565mm, 510mm and 479mm for the 95th%ile, 50th%ile and 5th%ile respectively. Seat depth posterior had a 95th%ile of 50mm. Seat width indicated 500mm for the 95th%ile.

Backrest height had a 95th%ile and 5th%ile of 555mm and 449mm and backrest width had a 5th%ile of 400mm. The 95th%ile and 5th%ile for lumbar support height and edge of lumbar support were 201mm, 157mm and 171mm, 127mm respectively. The 50th%ile for backrest point and lumbar support point were 575mm and 510mm respectively. The 50th%ile for cushion depth was 60mm.

The average armrest height was 182±18mm, the 95th%ile was 212mm and the 5th%ile was 160mm. The average armrest length was 257±16mm and the 50th%ile for armrest length was 258mm. The average thigh height was 127±16mm, the 95th%ile was 156mm and the 5th%ile was 109mm.

Table XVIII: The main anthropometric chair structural dimensions of the South African sample.

	Total South African Sample	Total Female Sample	Total Male Sample	Black Female Sample	White Female Sample	Coloured Female Sample	Indian/Asian Female Sample	Black Male Sample	White Male Sample	Coloured Male Sample	Indian/Asian Male Sample
SEAT HEIGHT MINIMUM (mm)	360	350	400	350	360	354	330	390	410	403	389
SEAT HEIGHT MAXIMUM (mm)	470	447	480	430	468	443	447	480	480	485	470
SEAT DEPTH ANTERIOR (mm)	460	460	460	470	460	460	446	460	470	450	479
SEAT DEPTH POSTERIOR (mm)	70	70	50	70	70	60	52	50	50	40	50
SEAT WIDTH (mm)	560	580	520	580	460	520	562	520	520	515	500
BACKREST HEIGHT MINIMUM (mm)	420	420	430	420	438	427	418	430	480	415	449
BACKREST HEIGHT MAXIMUM (mm)	550	527	570	510	542	550	504	550	580	528	555
BACKREST WIDTH (mm)	460	480	440	480	460	460	440	430	460	440	470
ARMREST HEIGHT MINIMUM(mm)	145	150	140	149	160	144	160	130	160	146	160
ARMREST HEIGHT MAXIMUM (mm)	235	234	240	230	240	233	212	225	250	240	212
ARMREST LENGTH (mm)	250	240	260	245	240	235	230	260	260	250	258
LUMBAR SUPPORT HEIGHT MINIMUM (mm)	150	150	140	160	150	134	130	140	140	135	157
LUMBAR SUPPORT HEIGHT MAXIMUM (mm)	250	260	220	260	222	200	213	210	220	208	201
EDGE OF LUMBAR SUPPORT HEIGHT MINIMUM (mm)	120	250	110	130	120	104	100	110	110	105	127
EDGE OF LUMBAR SUPPORT HEIGHT MAXIMUM (mm)	220	230	190	230	192	170	183	180	190	178	171
BACKREST POINT (mm)	580	580	580	580	570	545	550	590	590	560	575
LUMBAR SUPPORT POINT (mm)	510	510	520	510	510	490	500	520	530	510	510
CUSHION DEPTH (mm)	60	60	60	70	60	60	60	60	60	50	60

ANTHROPOMETRIC SEAT PAN MEASURES

Table XVIII represents the main anthropometric chair structural dimensions for the South African sample and each ethnic group. The minimum seat height (5^{th}%ile) ranged from 330mm to a maximum of 410mm (80mm difference). The Indian/Asian female sample had the shortest seat height (330mm) and the White male sample had the tallest seat height (410mm). The male sample had a greater minimum seat height compared to the female sample (50mm difference). The maximum seat height (95^{th}%ile) ranged between 430mm and 485mm. The Black female sample obtained the shortest seat height result and the Coloured male sample obtained the tallest seat height result. The seat height from the South African sample would need to be adjusted between 330mm to 485mm to accommodate each ethnic group. Seat depth posterior (95^{th}%ile) ranged from 40mm to 70mm. The seat depth posterior would need to be 70mm to accommodate the Black and White female samples. The seat width (95^{th}%ile) would need to be 580mm as this is the largest width. The Black female sample obtained the largest seat width and the White female sample obtained the smallest seat width (460mm).

ANTHROPOMETRIC BACKREST MEASUREMENTS

The minimum backrest height (5^{th}%ile) would need to range between the 415mm measurement obtained from the Coloured male sample, and 480mm obtained from the White male sample. The maximum backrest height (95^{th}%ile) would need to range between the 504mm obtained from the Indian/Asian female sample and the 580mm obtained from the White male sample. Therefore, the backrest height would need to be adjustable to between 415mm and 580mm to accommodate the different ethnic groups in this study. The backrest width (50^{th}%ile) would need to be 460mm for the South African sample; however, this would be too narrow for the Black female sample (by 20mm) and the Indian/Asian male sample (by 10mm). The backrest cushion depth (50^{th}%ile) should be adjustable to between the 50mm obtained from the Coloured male sample and the 70mm obtained from the Black female sample. The backrest point (50^{th}%ile) would need to be adjustable to between 545mm (Coloured female sample) and 590mm (Black and White male samples) on the seat pan.

ANTHROPOMETRIC ARMREST MEASURES

The minimum armrest height (5^{th}%ile) would need to be adjustable between the shortest armrest height obtained from the Black male sample (130mm) and the tallest armrest height obtained from the White male and female sample and Indian/Asian male and female sample (160mm). The maximum armrest height (95^{th}%ile) would need to range between the 212mm obtained from the Indian/Asian male and female sample and the 250mm obtained from the White male sample. Therefore; armrest height would need to be adjustable between 130mm and 250mm to accommodate all ethnic groups. Armrest length (50^{th}%ile) would need to be 250mm for the South African sample; however, if possible to make it adjustable, it would range between 230mm and 260mm.

ANTHROPOMETRIC LUMBAR SUPPORT MEASURES

The lumbar support height and edge of lumbar support height would need to range between the 5^{th}%ile and 95^{th}%ile to accommodate the area for the buttocks. The minimum lumbar support height (130mm) and edge of lumbar support height (100mm) was obtained from the Indian/Asian female sample. The maximum lumbar support height (160mm) and edge of lumbar support height (230mm) was obtained from the Black female sample. This indicates that the Indian/Asian female sample would need the smallest area for the buttocks and the Black female sample would need the greatest area for the buttocks. The lumbar support point (50^{th}%ile) would need to be adjustable between 490mm (Coloured female sample) and 530mm (White male sample) on the seat pan.

ETHNIC AND SEX EFFECT ON ANTHROPOMETRIC CHAIR MEASUREMENTS

The figures below represent the average values for each variable.

SEAT PAN MEASURES

SEAT HEIGHT/POPLITEAL HEIGHT

(Refers to seat height, Figure 8)

There is a significant impact of sex on seat height ($p<0.01$) as well as a significant impact of ethnic groups on seat height ($p<0.01$) however, no significant difference was observed for sex and ethnic group interaction on seat height ($p>0.05$; see appendix C2).

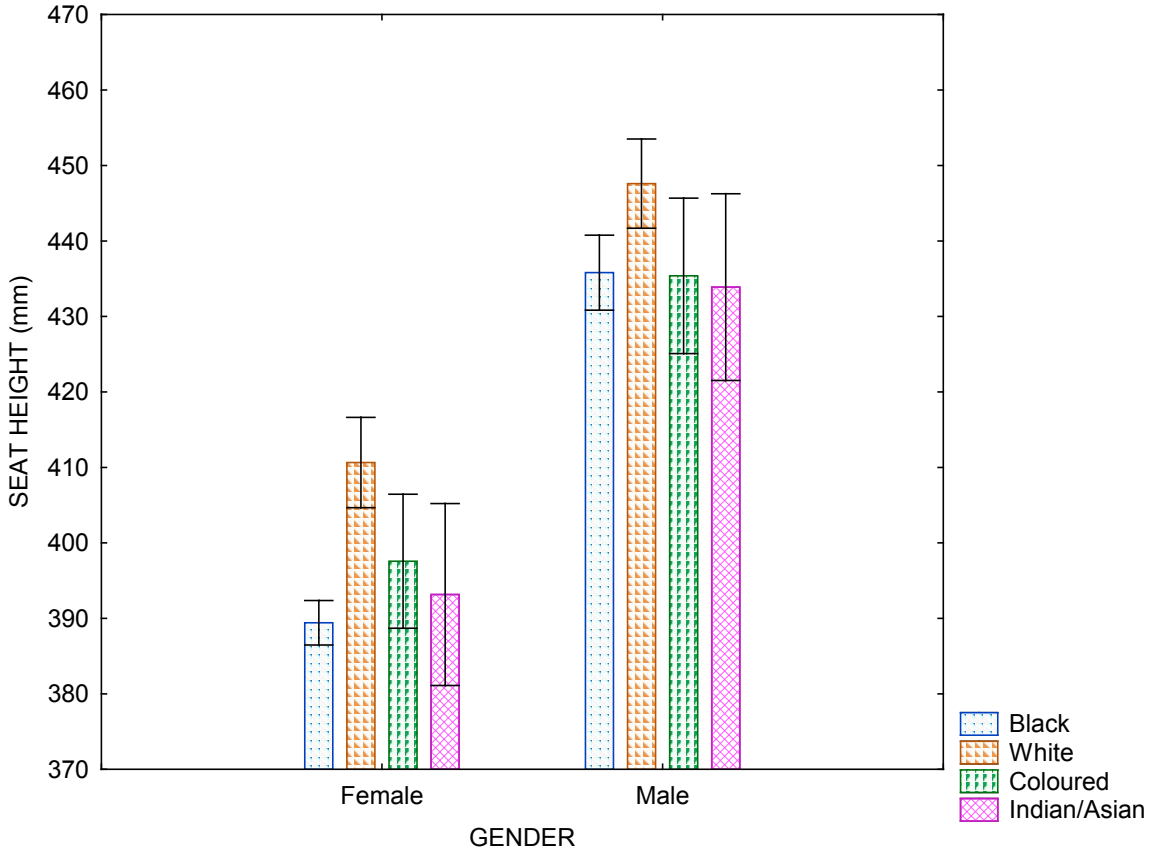

Figure 21: Seat height considering 'ethnic groups' and 'gender'**.**

indicates significant difference ($p<0.01$).

Figure 21 indicates the significant difference for seat height within the female sample: the White female group had a significantly greater ($p<0.01$) average seat height

(411±35mm) compared to the Black female average seat height (389±24mm) The male sample had a 46mm greater seat height compared to the female sample (see appendix C3).

SEAT DEPTH ANTERIOR/LEG LENGTH
(Refers to seat depth anterior, Figure 8)

A significant impact of sex and ethnic group was observed for seat depth anterior ($p<0.01$); however no significant difference was observed for the interaction of sex and ethnic groups on seat depth anterior ($p>0.05$; see appendix C2).

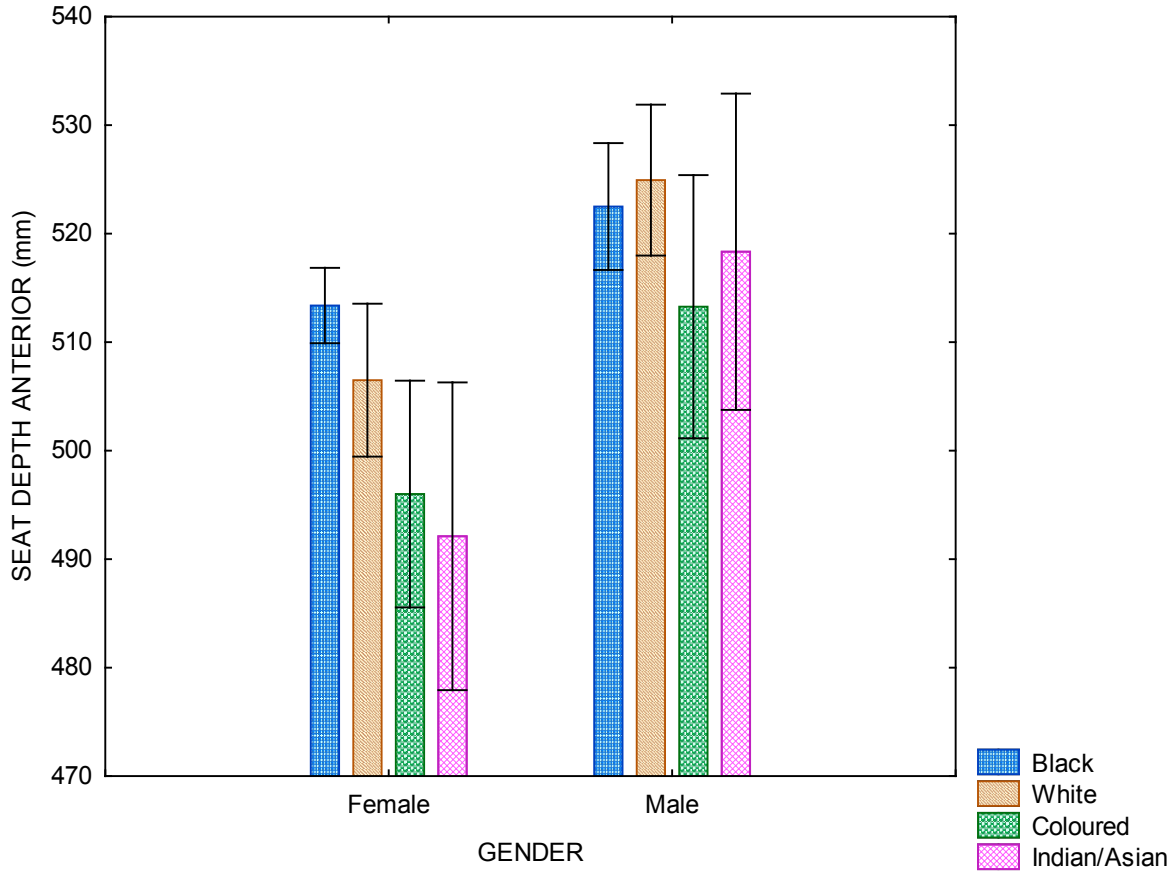

Figure 22: Seat depth anterior considering 'ethnic groups' and 'gender'.

There was large variance for seat depth anterior within the male and female groups as seen in Figure 22. The Indian/Asian ethnic group displayed the largest variance in seat depth anterior, and the Black ethnic group had the smallest variance. The male sample had an average seat depth anterior of 522±35mm and the female sample had a shorter seat depth anterior (510±30mm). A shorter seat length would be required

for the Indian/Asian female sample as this group obtained an average seat length anterior of 492±37mm (see appendix C3).

SEAT DEPTH POSTERIOR/BUTTOCKS LENGTH
(Refers to seat depth posterior, Figure 8)

Significant differences were only observed for sex on seat depth posterior ($p<0.01$). Ethnic groups and the interaction between gender and ethnic groups had no significant impact on seat depth posterior ($p>0.05$; see appendix C2).

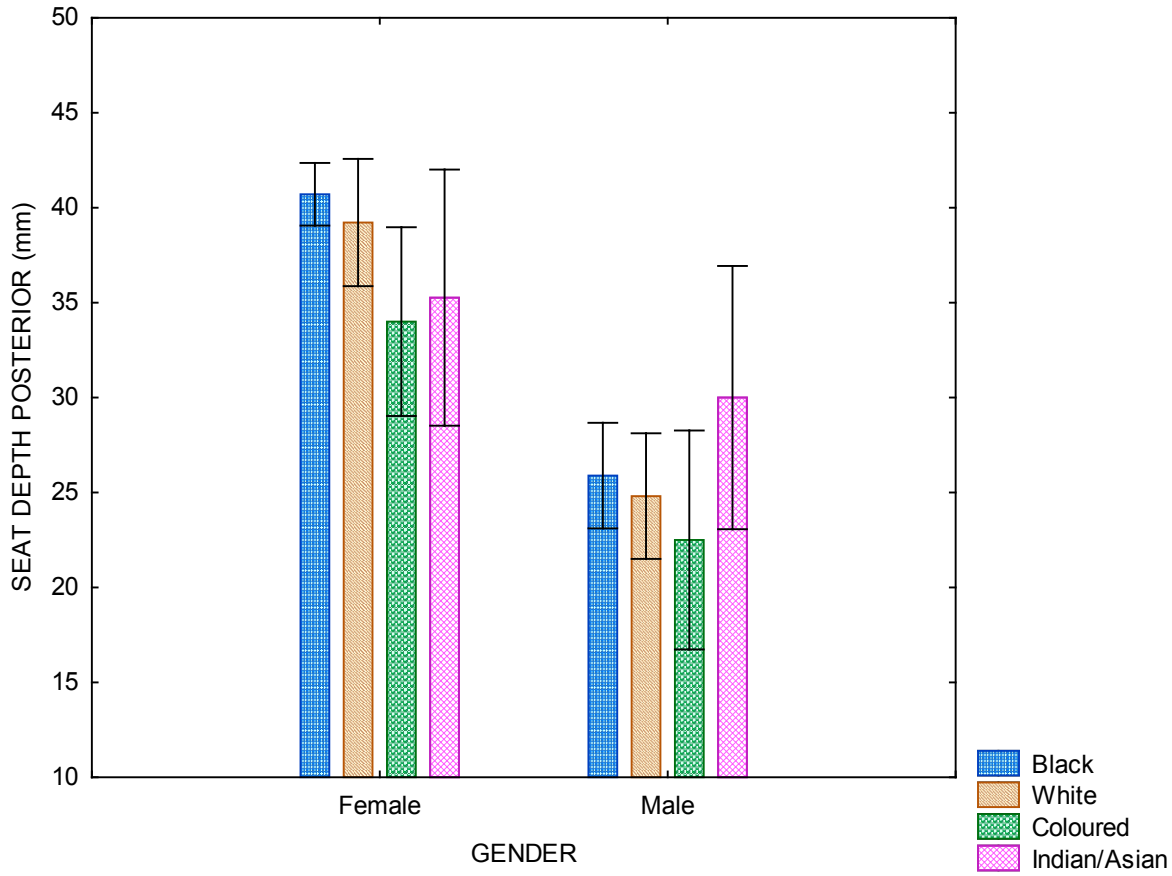

Figure 23: Seat depth posterior considering 'ethnic groups' and 'gender'.

Figure 23 indicated no significant differences within gender groups (see Appendix C3). The total South African sample had a seat depth posterior of 70mm. The total female sample had a seat depth posterior of 70mm and the total males sample had a depth of 50mm. This indicates that a seat depth posterior measurement needs to be implemented for office chair design. Many studies and office chair dimensions do not consider a seat depth posterior measurement.

SEAT WIDTH/HIP WIDTH
(Refers to seat width, Figure 8)

Sex and ethnicity had a significant impact on seat width ($p<0.01$; see appendix C2).

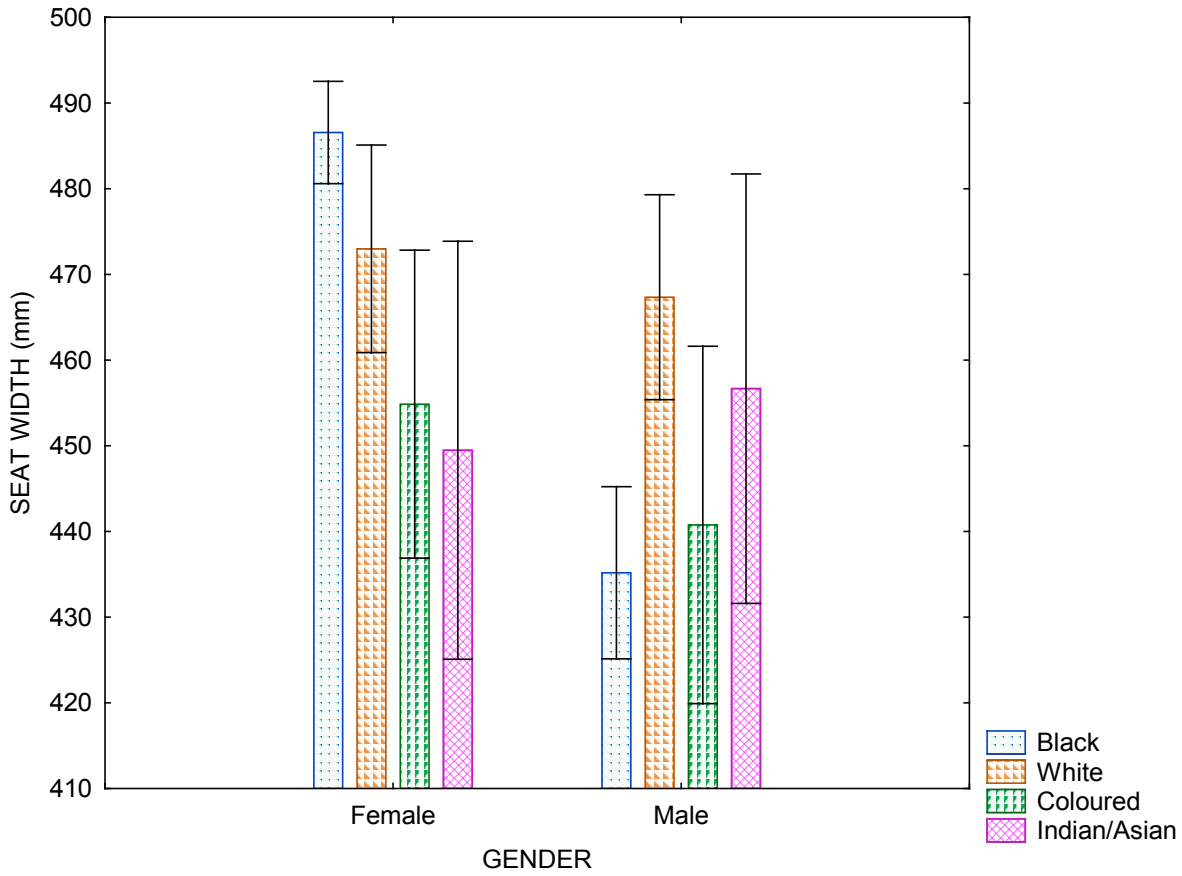

Figure 24: Seat width considering 'ethnic groups' and 'gender'.

indicates significant difference ($p<0.05$).

Figure 24 indicated that the White male group had a significantly greater ($p<0.05$) seat width (470±40mm) compared to the average Black male seat width (435±49mm). The Black female group had the largest seat width (487±60mm) compared to the other ethnic groups. This Black female sample was the main concern as a larger seat pan would need to be manufactured in order to accommodate the entire South African sample, including the Black female sample (see appendix C3).

THIGH HEIGHT

It was observed that there was a significant impact of ethnic groups on thigh height ($p<0.01$), as well as a significant impact of the interaction between gender and ethnic groups on thigh height ($p<0.05$; see appendix C2).

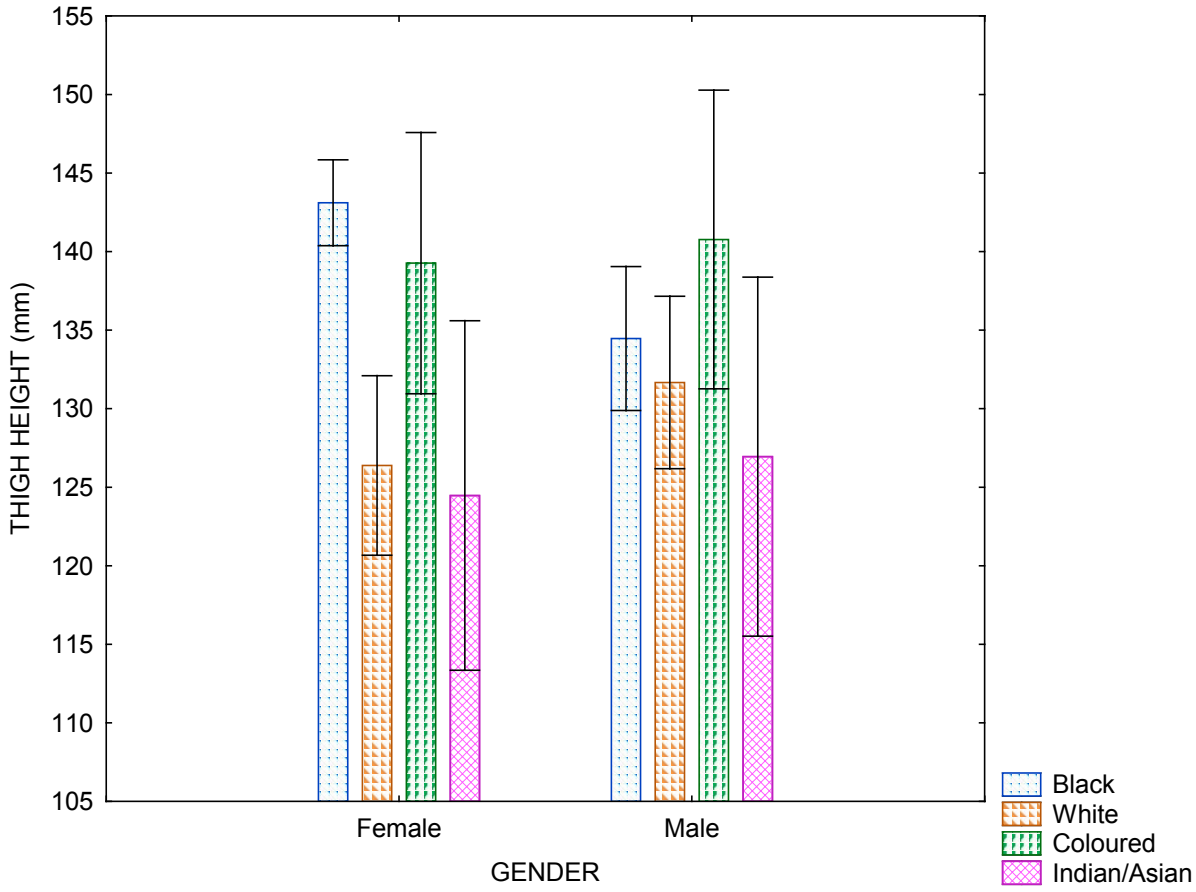

Figure 25: Thigh height considering 'ethnic groups' and 'gender'.

indicates significant difference ($p<0.01$).

The Black female group had a significantly greater ($p<0.01$) thigh height (143±27mm) compared to the average White female thigh height (126±23mm). A large variation of thigh height occurred for the South African sample as indicated in Figure 25. The Black female group had the largest average thigh height within the female sample and the Coloured male group had the largest average thigh height (141±19mm) within the male group (see appendix C3).

BACKREST MEASURES

BACKREST HEIGHT
(Refers to backrest height, Figure 8)

Significant impacts of sex, ethnic groups and the interaction between gender and ethnic groups were observed for backrest height ($p<0.01$; see appendix C2).

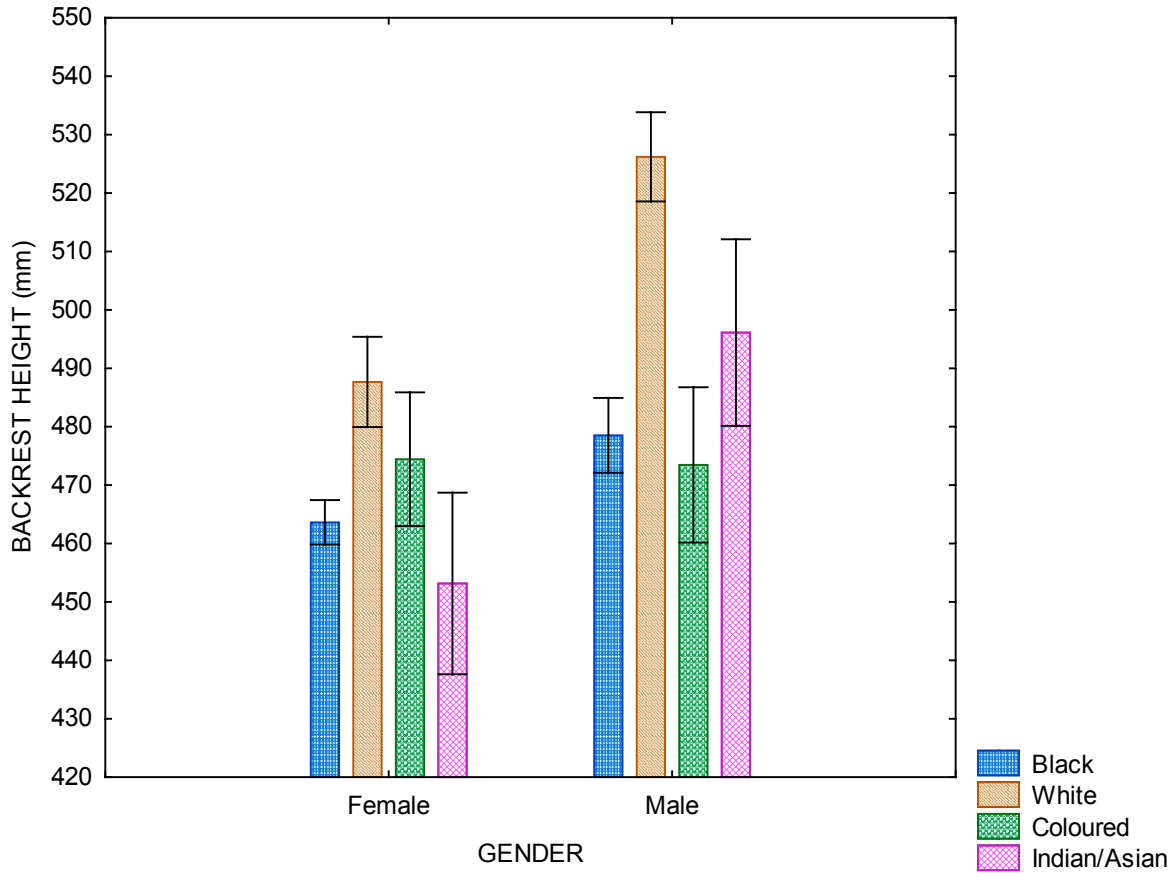

Figure 26: Backrest height considering 'ethnic groups' and 'gender'.

indicates significant difference ($p<0.05$).

Figure 26 indicated that the White female group required a significantly greater ($p<0.05$) backrest height (488±35mm) compared to the average Black female backrest height (464±31mm), as well as the Indian/Asian backrest height (453±34mm). A significant difference ($p<0.01$) was observed between the White male backrest height (530±40mm) and Black male backrest height (479±40mm) as well as between the White male and Coloured male backrest height (473±33mm). The White

male group had the greatest backrest height compared to the South African sample (see appendix C3).

BACKREST WIDTH
(Refers to backrest width, Figure 8)

Sex and ethnicity had a significant impact on backrest width ($p<0.01$). A significant impact of the interaction of gender and ethnic groups on backrest width was also observed ($p<0.01$; see appendix C2).

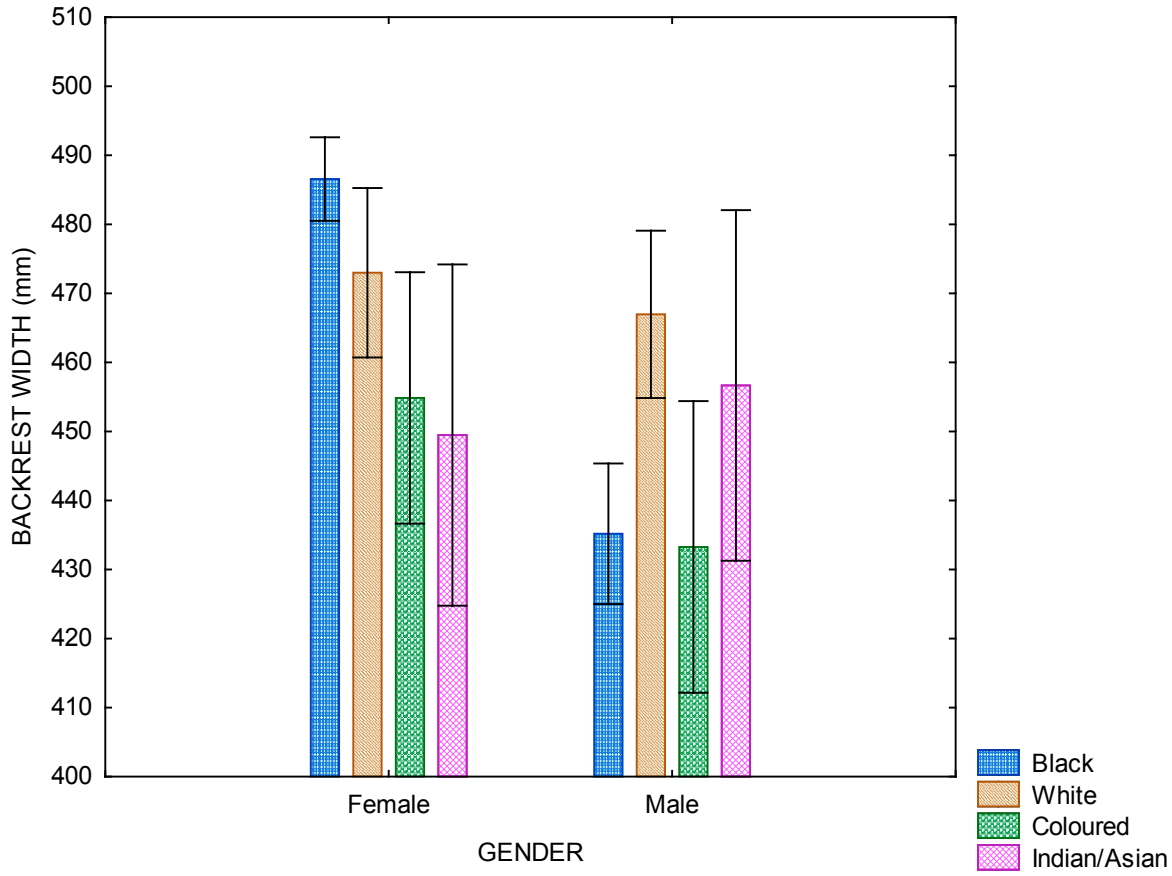

Figure 27: Backrest width considering 'ethnic groups' and 'gender'.

indicates significant difference ($p<0.05$).

The White male group had a significantly greater ($p<0.05$) backrest width (470±40mm) measurement compared to the average Black male backrest width measurement, as can be seen in Figure 75. The Black female group had the largest backrest width (487±49mm) measurement, compared to the other ethnic groups (see appendix C3).

BACKREST POINT

It was observed that there was a significant impact of ethnic groups and of the interaction between sex and ethnic groups for backrest point ($p<0.05$; see Appendix C2).

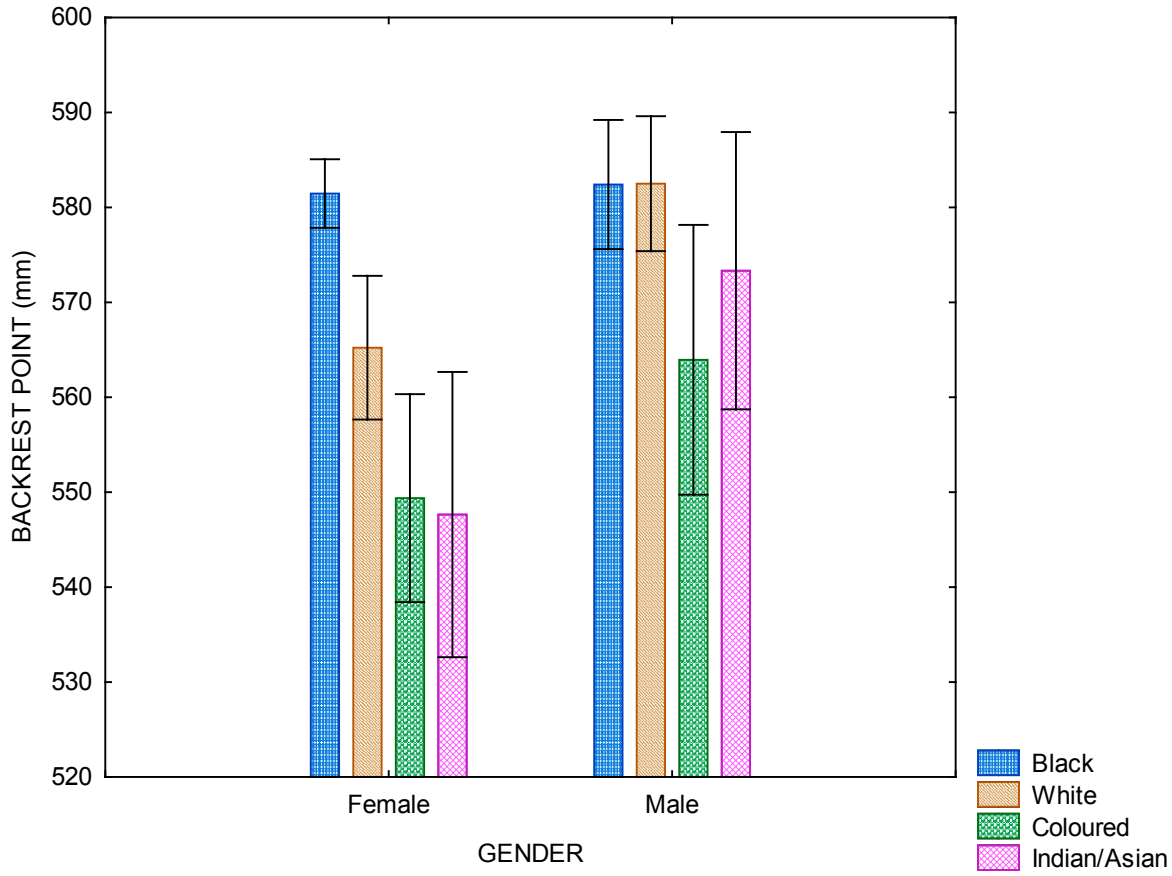

Figure 28: Backrest point considering 'ethnic groups' and 'gender'.

Figure 28 indicated that the Black female group had the largest backrest point (581±29mm) measurement compared to the other female groups. Similar backrest point values were observed for the Black male group (582±39mm) and White male group (580±30mm; see Appendix C3).

CUSHION DEPTH

The interaction between sex and ethnic groups had a significant impact on cushion depth ($p<0.01$; see Appendix C2).

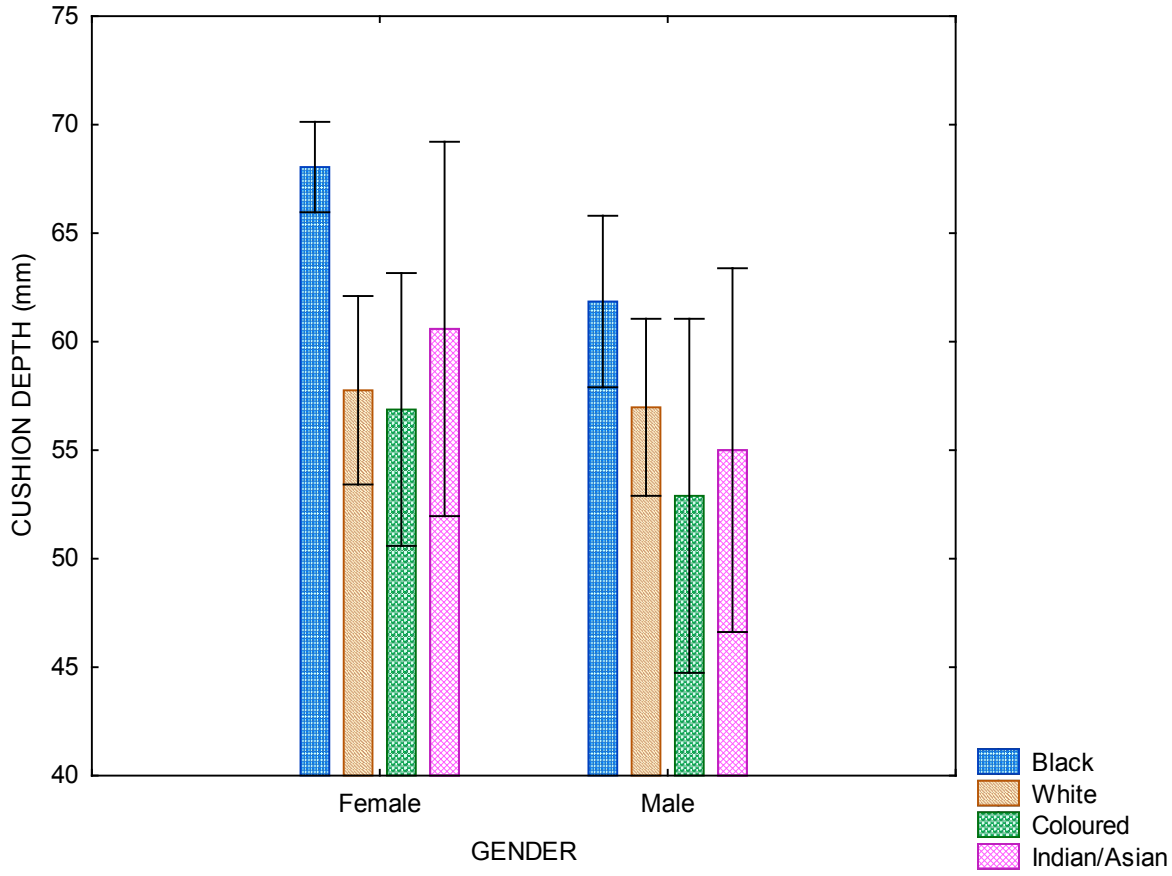

Figure 29: Cushion depth considering 'ethnic groups' and 'gender'.

As can be observed in Figure 29, the Black female group had the largest average cushion depth (63±25mm) measurement when compared to the entire South African sample (see Appendix C3).

LUMBAR SUPPORT MEASUERS

LUMBAR SUPPORT HEIGHT
(Refers to lumbar support height, Figure 8)

It was observed that there was a significant impact of sex and ethnic groups on lumbar support height ($p<0.01$), as well as a significant impact of the interaction between sex and ethnic groups on lumbar support height ($p<0.01$; see appendix C2).

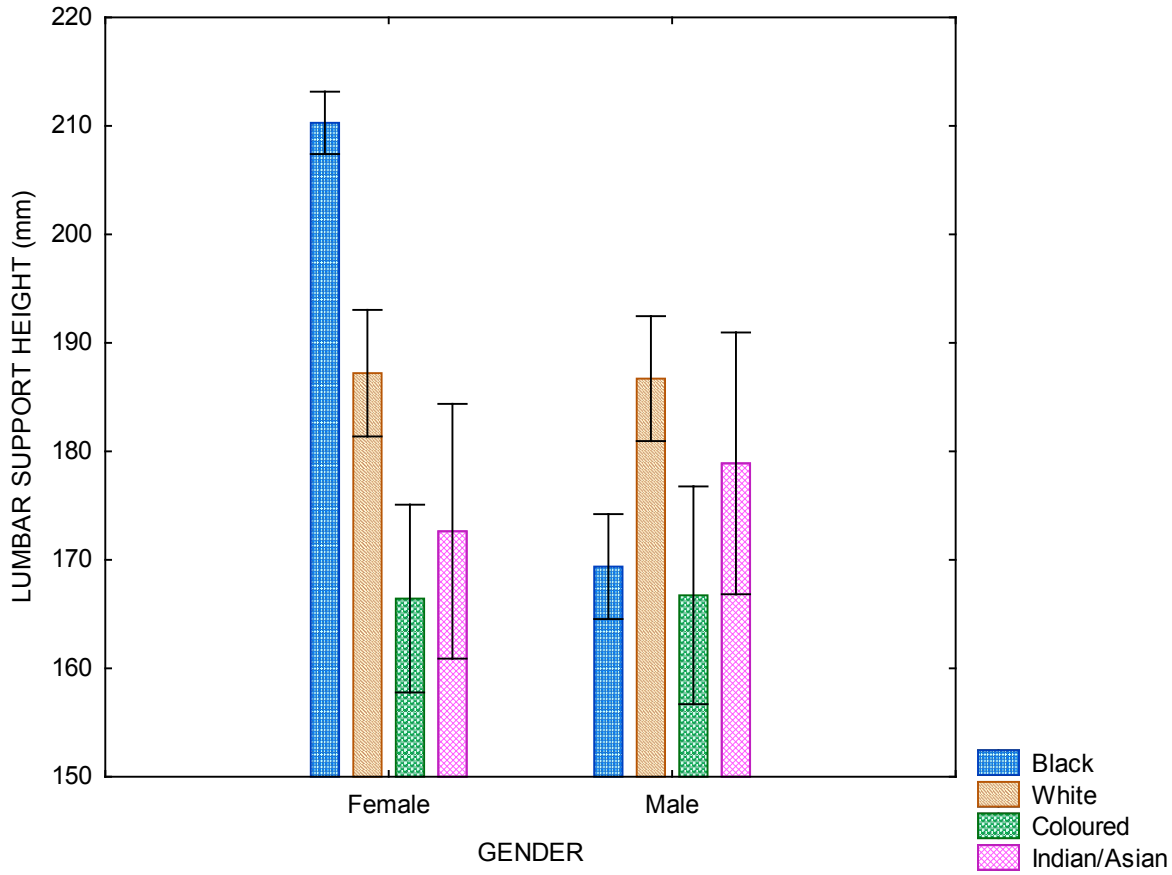

Figure 30: Lumbar support height considering 'ethnic groups' and 'gender'.

indicates significant difference ($p<0.01$).

Figure 30 indicates that the Black female group had a significantly greater ($p<0.01$) average lumbar support height (210±30mm) measurement compared to the White female lumbar support height (187±24mm), Coloured female lumbar support height (166±20mm) as well as the Indian/Asian female lumbar support height (173±29mm). A significant difference ($p<0.01$) was also observed between the average White male

lumbar support height measurement (176±23mm) and Black male lumbar support height (169±20mm; see appendix C3). The Black female group had the greatest lumbar support height measurement compared to the other ethnic groups; this indicates that the Black female group needs a comparatively larger space between the lumbar support and seat pan to accommodate the buttocks

EDGE OF LUMBAR SUPPORT HEIGHT
(Refers to edge of lumbar support height, Figure 8)

Sex and ethnicity had a significant impact on the edge of lumbar support height ($p<0.01$), as well as a significant impact for the interaction between sex and ethnic groups on the edge of lumbar support height ($p<0.01$; see appendix C2).

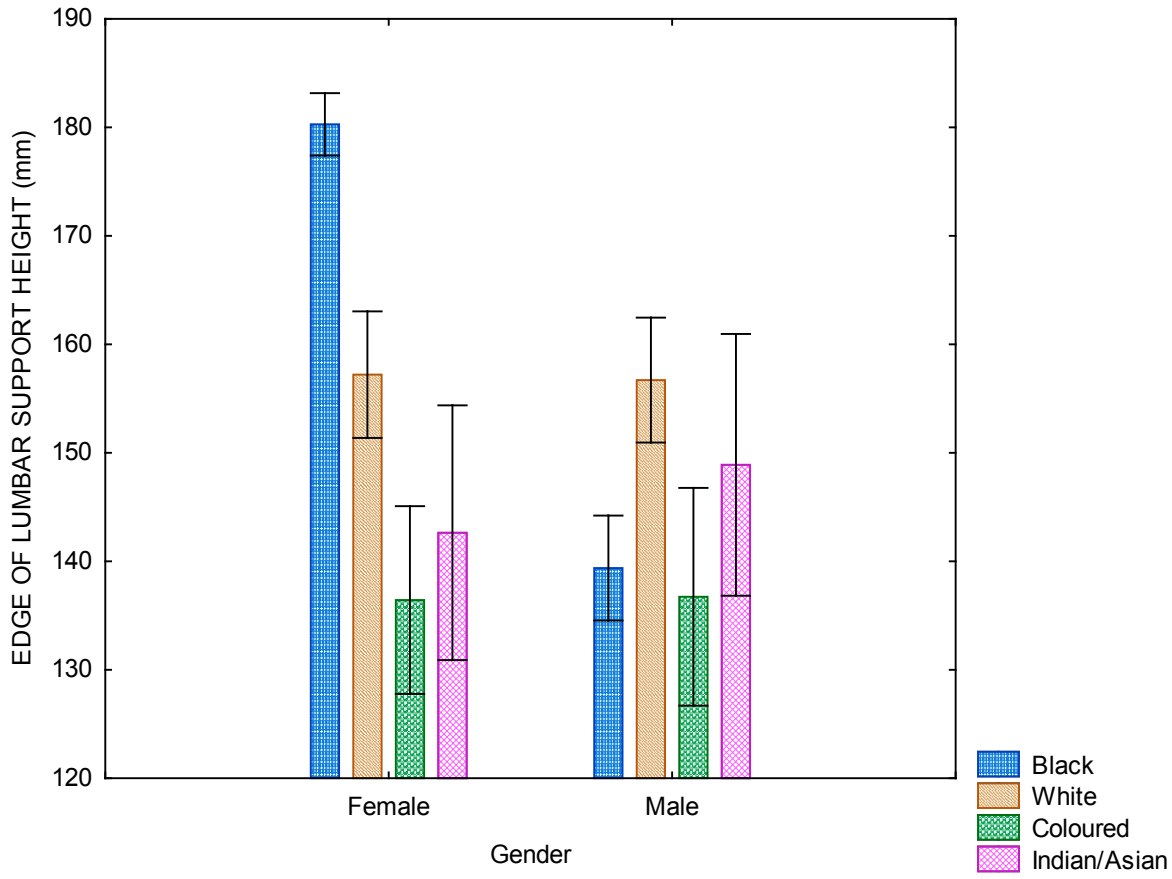

Figure 31: Edge of lumbar support height considering 'ethnic groups' and 'gender'. indicates significant difference ($p<0.01$).

The edge of lumbar support height values followed a similar trend that was observed for the lumbar support height values. Figure 31 indicated that the Black female group had a significantly greater ($p<0.01$) lumbar support height (180±30mm) compared to the average White female edge of lumbar support height (157±24mm), between the Black female group and Coloured female group (109±28mm) as well as between the Black female group and Indian/Asian female group (143±29mm). Significant difference ($p<0.01$) was also observed between the average White male value (146±23mm) and Black male group value (139±20mm; see appendix C3).

LUMBAR SUPPORT POINT

A significant impact was observed for sex and ethnic groups for lumbar support point ($p<0.01$; see appendix C2).

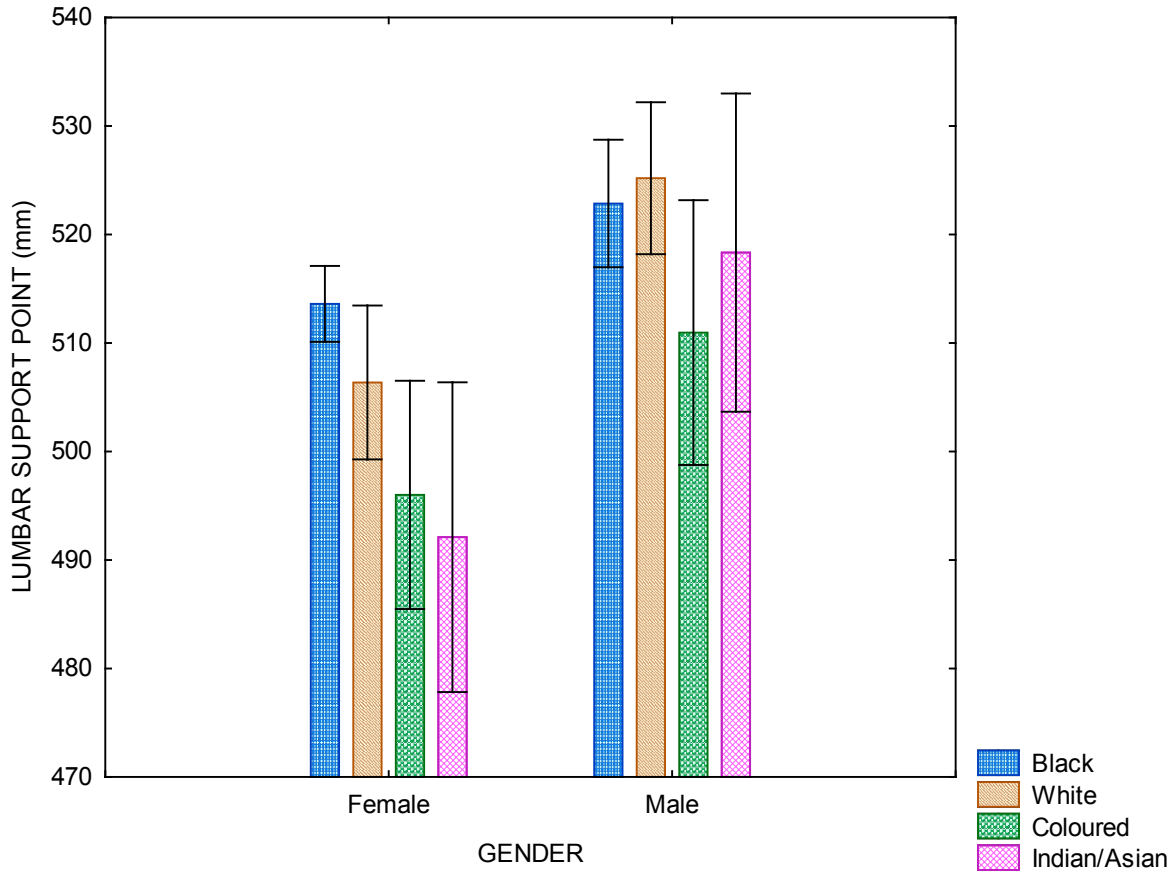

Figure 32: Lumbar support point considering 'ethnic groups' and 'gender'.

Figure 32 indicates that a large variation for lumbar support point was observed for the South African sample. The male sample had a greater lumbar support point (522±35mm) compared to the female lumbar support point (510±30mm; see Appendix C3).

ARMREST MEASUREMENTS

ARMREST HEIGHT/ELBOW HEIGHT
(Refers to armrest height, Figure 8)

It was observed that there was a significant impact of sex and also of the interaction of gender and ethnic groups on armrest height ($p<0.05$; see appendix C2).

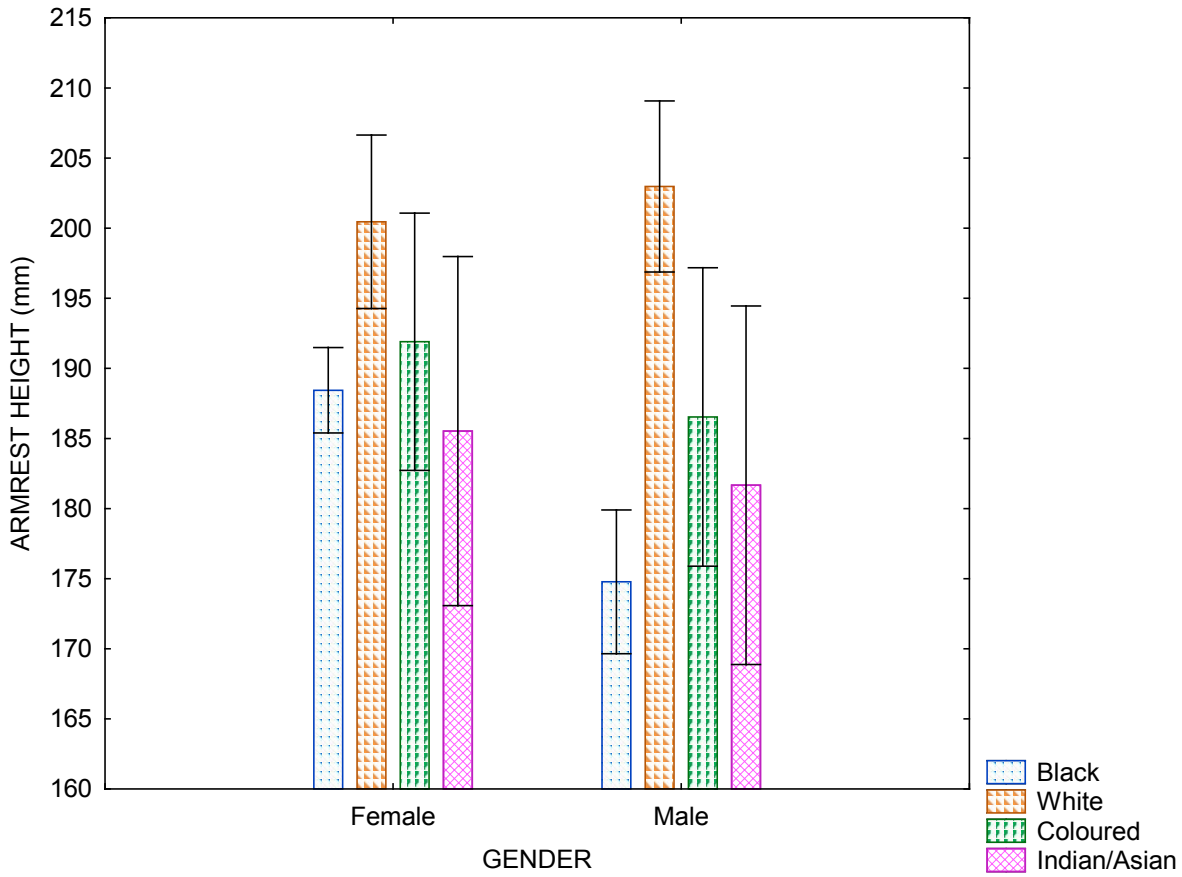

Figure 33: Armrest height considering 'ethnic groups' and 'gender'.

The White male group had a significantly greater ($p<0.01$) armrest height (200±30mm) compared to the average Black male armrest height (175±29mm). It

was observed that the White male group had the greatest armrest height compared to the other male groups and the White female group had the greatest armrest height (200±25mm) compared to the other female groups (see Appendix C3).

ARMREST LENGTH /ARM LENGTH
(Refers to armrest length, Figure 8)

Sex and ethnicity had a significant impact on armrest length ($p<0.01$; see Appendix C2).

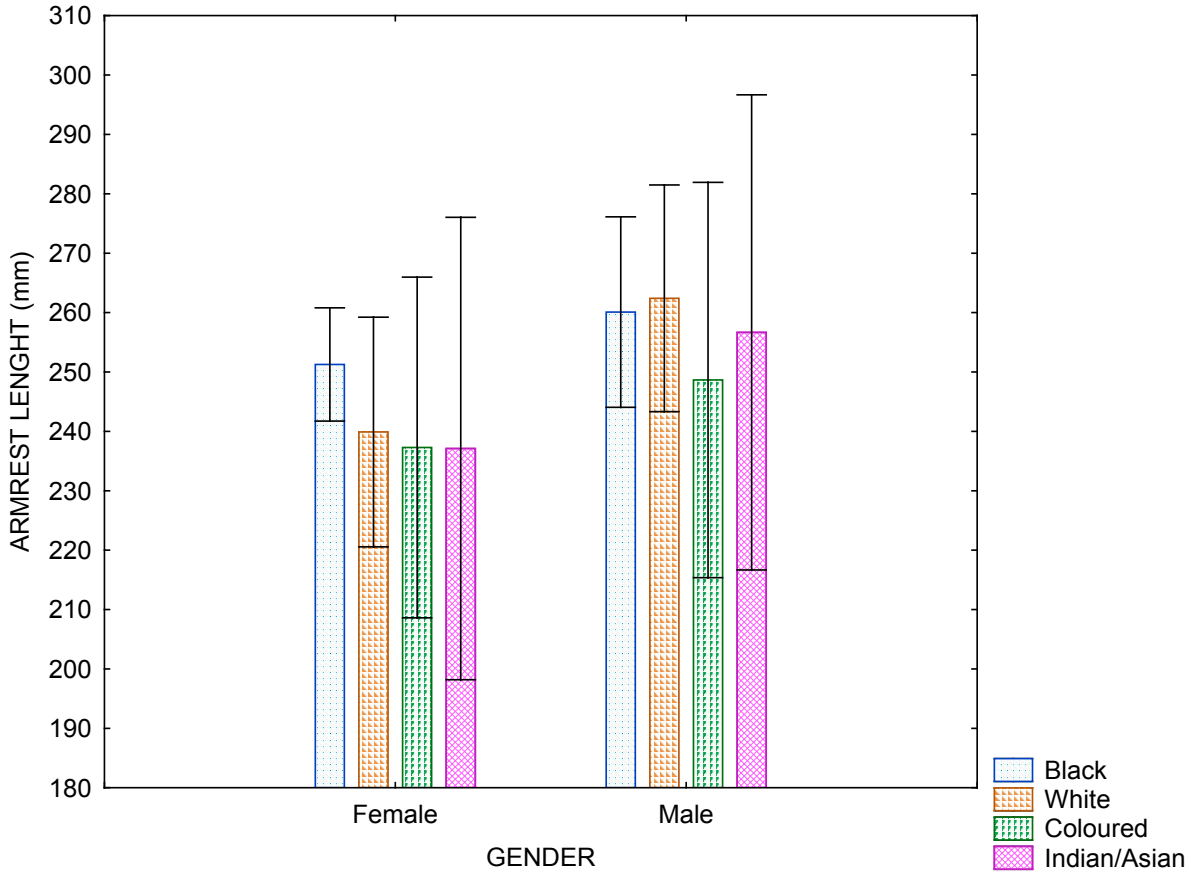

Figure 34: Armrest length considering 'ethnic groups' and 'gender'.

A large variation for armrest length was observed for the South African sample. The total female sample had an armrest length measurement of 248±10mm and the total male sample had an armrest length measurement of 259±23mm (see Appendix C3).

CORRELATIONS FOR ANTHROPOMETRIC CHAIR DIMENSIONS FOR THE SOUTH AFRICAN SAMPLE

Anthropometric chair dimension correlations were calculated to identify if any one anthropometric chair variable influenced another chair variable.

ANTHROPOMETRIC CHAIR DIMENSIONS: SEAT PAN

Table XIX: Part 1/3, Correlations for anthropometric chair dimensions (marked correlations are significant, p<0.05).

	SEAT HEIGHT	SEAT DEPTH ANTERIOR	SEAT DEPTH POSTERIOR	SEAT WIDTH	THIGH HEIGHT
SEAT HEIGHT	1.00	**0.38**	**-0.26**	-0.06	-0.02
SEAT DEPTH ANTERIOR	**0.38**	1.00	**-0.20**	**0.27**	**0.19**
SEAT DEPTH POSTERIOR	**-0.26**	**-0.20**	1.00	**0.36**	**0.23**
SEAT WIDTH	-0.06	**0.27**	**0.36**	1.00	**0.62**
THIGH HEIGHT	-0.02	**0.19**	**0.23**	**0.62**	1.00
BACKREST HEIGHT	**0.56**	**0.28**	-0.04	**0.13**	**0.09**
BACKREST WIDTH	-0.07	**0.27**	**0.36**	**0.99**	**0.60**
BACKREST POINT	**0.24**	**0.83**	**-0.13**	**0.22**	**0.19**
CUSHION DEPTH	**-0.25**	**-0.28**	**0.12**	-0.07	0.01
LUMBAR SUPPORT HEIGHT	**-0.22**	**0.14**	**0.37**	**0.42**	**0.30**
EDGE OF LUMBAR SUPPORT HEIGHT	**-0.22**	**0.14**	**0.37**	**0.42**	**0.30**
LUMBAR SUPPORT POINT	**0.38**	**1.00**	**-0.19**	**0.26**	**0.19**
ARMREST HEIGHT	0.06	0.00	**0.11**	**0.30**	**0.30**
ARMREST LENGTH	**0.10**	**0.13**	0.00	0.06	0.05

A positive, significant correlation was observed between seat height and seat depth anterior (0.38) and a negative, significant correlation was observed for seat depth posterior and seat height (-0.26). A strong positive correlation was observed for seat height and backrest height (0.56). Seat depth anterior had a strong, positive correlation with backrest point (0.83) and lumbar support point (1.00). The longer the upper leg and the further back an individual sits on the seat pan, the further the backrest point and lumbar support will be situated posteriorly. Seat depth anterior had a negative, significant correlation with seat depth posterior. Seat width had a

strong, positive correlation with thigh height (0.62) and backrest width (0.60). The larger the hip breadth, the larger the participant's thigh height.

ANTHROPOMETRIC CHAIR DIMENSIONS: BACKREST SUPPORT

Table XX: Part 2/3, Correlations for anthropometric chair dimensions (marked correlations are significant, $p<0.05$).

	BACKREST HEIGHT	BACKREST WIDTH	BACKREST POINT	CUSHION DEPTH
SEAT HEIGHT	**0.56**	-0.07	**0.24**	**-0.25**
SEAT DEPTH ANTERIOR	**0.28**	**0.27**	**0.83**	**-0.28**
SEAT DEPTH POSTERIOR	-0.04	**0.36**	**-0.13**	**0.12**
SEAT WIDTH	**0.13**	**0.99**	**0.22**	-0.07
THIGH HEIGHT	**0.09**	**0.60**	**0.19**	0.01
BACKREST HEIGHT	1.00	**0.13**	**0.15**	**-0.22**
BACKREST WIDTH	**0.13**	1.00	**0.23**	-0.07
BACKREST POINT	**0.15**	**0.23**	1.00	**0.29**
CUSHION DEPTH	**-0.22**	-0.07	**0.29**	1.00
LUMBAR SUPPORT HEIGHT	**0.11**	**0.43**	**0.18**	0.07
EDGE OF LUMBAR SUPPORT HEIGHT	**0.11**	**0.43**	**0.18**	0.07
LUMBAR SUPPORT POINT	**0.28**	**0.27**	**0.83**	**-0.29**
ARMREST HEIGHT	**0.45**	**0.29**	-0.03	-0.06
ARMREST LENGTH	**0.10**	0.07	**0.08**	**-0.08**

Backrest height had a strong positive correlation with seat height (0.56) and armrest height (0.45). Backrest width had a strong correlation with seat width (0.99) and thigh height (0.60), and also lumbar support height (0.83).

ANTHROPOMETRIC CHAIR DIMENSIONS: LUMBAR SUPPORT AND ARMRESTS

Table XXI: Part 3/3, Correlations for anthropometric chair dimensions (marked correlations are significant, p<0.05).

	LUMBAR SUPPORT HEIGHT	EDGE OF LUMBAR SUPPORT HEIGHT	LUMBAR SUPPORT POINT	ARMREST HEIGHT	ARMREST LENGTH
SEAT HEIGHT	**-0.22**	**-0.22**	**0.38**	0.06	**0.10**
SEAT DEPTH ANTERIOR	**0.14**	**0.14**	**1.00**	0.00	**0.13**
SEAT DEPTH POSTERIOR	**0.37**	**0.37**	**-0.19**	**0.11**	0.00
SEAT WIDTH	**0.42**	**0.42**	**0.26**	**0.30**	0.06
THIGH HEIGHT	**0.30**	**0.30**	**0.19**	**0.30**	0.05
BACKREST HEIGHT	**0.11**	**0.11**	**0.28**	**0.45**	**0.10**
BACKREST WIDTH	**0.43**	**0.43**	**0.27**	**0.29**	0.07
BACKREST SUPPORT POINT	**0.18**	**0.18**	**0.83**	-0.03	**0.08**
CUSHION DEPTH	0.07	0.07	**-0.29**	-0.06	**-0.08**
LUMBAR SUPPORT HEIGHT	1.00	**1.00**	**0.14**	**0.27**	0.06
EDGE OF LUMBAR SUPPORT HEIGHT	**1.00**	1.00	**0.14**	**0.27**	0.06
LUMBAR SUPPORT POINT	**0.14**	**0.14**	1.00	0.00	**0.13**
ARMREST HEIGHT	**0.27**	**0.27**	0.00	1.00	0.02
ARMREST LENGTH	0.06	0.06	**0.13**	0.02	1.00

A significant correlation was observed for the lumbar support height and edge of lumbar support height as this was a similar measure of the lumbar support structure. Lumbar support height and edge of lumbar support height had a significant correlation with seat width (0.42). The larger the hip breadth, the larger the space for the buttocks. The lumbar support point had a strong correlation with seat depth anterior (1.00) and backrest support point (0.83). The longer the upper legs, the further back an individual sits on the seat pan, this therefore results in a further posterior lumbar support point and backrest support point.

PARTICIPANT AND ANTHROPOMETRIC CHAIR DIMENSION CORRELATIONS

Table XXII: Correlations for participant and chair dimensions (marked correlations are significant, p<0.05).

	AGE	STATURE	SHOULDER HEIGHT	MASS	BMI	WAIST CIRCUM.	HIP CIRCUM.	WHR
SEAT HEIGHT	**0.15**	**0.81**	**0.79**	**0.21**	**-0.16**	0.04	**-0.15**	**0.24**
SEAT DEPTH ANTERIOR	0.05	**0.44**	**0.44**	**0.30**	**0.09**	**0.25**	**0.17**	**0.13**
SEAT DEPTH POSTERIOR	-0.06	**-0.24**	**-0.22**	**0.18**	**0.29**	**0.17**	**0.36**	**-0.17**
SEAT WIDTH	**0.09**	-0.01	0.02	**0.69**	**0.70**	**0.64**	**0.75**	0.08
THIGH HEIGHT	**-0.09**	0.05	0.07	**0.72**	**0.71**	**0.58**	**0.73**	0.05
BACKREST HEIGHT	**0.12**	**0.70**	**0.67**	**0.36**	0.03	**0.19**	**0.09**	**0.18**
BACKREST WIDTH	**0.09**	-0.01	0.02	**0.69**	**0.69**	**0.64**	**0.75**	0.07
BACKREST POINT	-0.03	**0.32**	**0.30**	**0.23**	0.07	**0.21**	**0.15**	**0.10**
CUSHION DEPTH	**-0.13**	**-0.22**	**-0.25**	**-0.13**	-0.03	-0.06	-0.03	-0.04

Circum. = circumference

A strong positive correlation was observed between seat height and stature (0.81) and seat height and shoulder height (0.79). Seat depth anterior also had a positive correlation with stature (0.44) and shoulder height (0.44). This indicates that the taller the individual, the longer the lower and upper leg length. Stature and shoulder height had a strong correlation with backrest height (0.70 and 0.67 respectively). Body mass had a strong positive correlation with seat width (0.69), thigh height (0.72) and backrest width (0.69). BMI also had a strong positive correlation between seat width (0.70), thigh height (0.71), and backrest width (0.69). The larger the body mass and BMI, the larger the individual's hip breadth, thigh height and backrest support. Waist and hip circumference both had a strong, positive correlation for seat width (0.64 and 0.75 respectively), thigh height (0.58 and 0.73 respectively) and backrest width (0.64 and 0.75 respectively).

FINAL STUDY ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS

The sample (n=683) provided anthropometric chair dimensions in order for a specific office chair to be designed and manufactured for the South African population. Percentiles were calculated from the chair measures and this informed the construction of a demo chair.

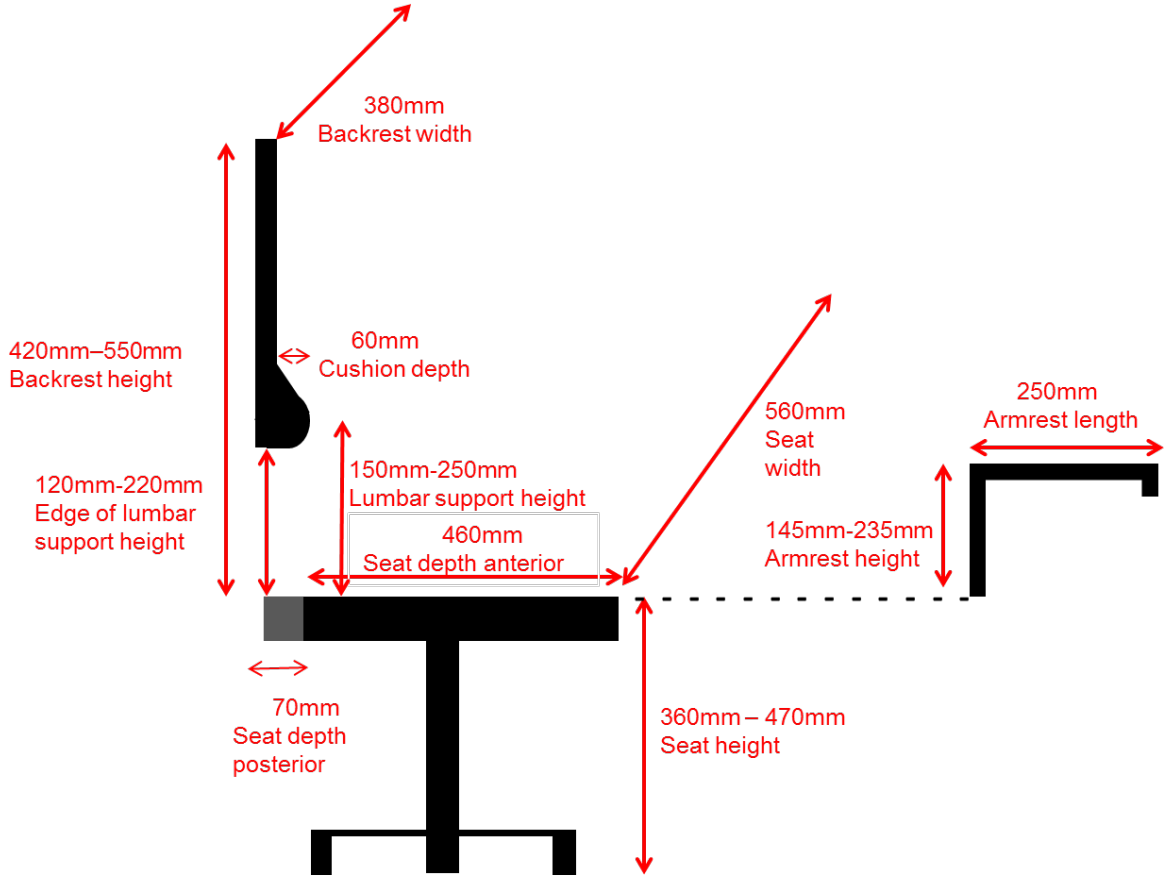

Figure 35: Anthropometric office chair dimensions according to the total South African sample (n=683).

Figure 35 is a graphical representation of the total South African anthropometric office chair dimensions. The office chair is depicted from the side. Arrows indicate the length of each structure of the office chair. Seat height incorporated the 5th to 95th%ile; seat pan width included the 95th%ile; seat depth anterior indicated the 5th%ile and seat depth posterior incorporated the 95th%ile. Backrest height included the 5th to 95th%ile; backrest width included the 50th%ile; the lumbar support height and edge of lumbar support height included the 5th to 95th%ile and the cushion depth incorporated the 50th%ile. Armrest height included the 5th to 95th%ile and armrest length incorporated the 50th%ile.

DEMO CHAIR

The Human Kinetics and Ergonomics department engineer constructed the ergonomic office chair. The measurements that were recorded around South Africa were then used to design and construct an office chair according to the anthropometric dimensions obtained. The office chair was reconstructed from the medium back “Jazz” office chair, manufactured by Cecil Nurse Business Furniture.

Figure 36: The redesigned office chair (A – anterior view, B – side view and C – posterior view.

The seat length anterior and posterior; backrest height; lumbar support height; edge of lumbar support height and the armrest height were modified to best suit the total South African sample dimension. Three seat pans were constructed to allow for three different seat pan lengths. The armrests were constructed to accommodate a greater range and the backrest was also modified in order to create a greater range for the lumbar support and edge of lumbar support.

COMPARISONS OF THE ORIGINAL OFFICE CHAIR AND REDESIGNED OFFICE CHAIR

The data collected from the South African sample were used to construct an office chair. The redesigned office chair was assembled using the structure of the “Jazz”, a medium back office chair. The redesigned office chair dimensions were compared to the dimensions of the “Jazz” chair to identify the main modifications that would need to be implemented in office chair design.

Table XXIII: Comparison of dimensions of the original office chair and the redesigned office chair.

Office Chair Structures	Original Office Chair: “Jazz"	Redesigned Office Chair
Seat Length (mm)	430	470 / 530 / 590
Seat Depth Posterior (mm)	20	70
Seat Height Minimum (mm)	440	440
Seat Height Maximum (mm)	560	560
Seat Width (mm)	480	480
Backrest Height Minimum (mm)	470	470
Backrest Height Maximum (mm)	550	550
Backrest Width (mm)	440	440
Armrest Length (mm)	260	260
Armrest Height Minimum (mm)	240	80
Armrest Height Maximum (mm)	240	330
Cushion Depth (mm)	40	50
Lumbar Support Height Minimum (mm)	120	150
Lumbar Support Height Maximum (mm)	220	260
Edge of Lumbar Support Height Minimum (mm)	0	110
Edge of Lumbar Support Height Maximum (mm)	80	230

The shaded areas indicate the main differences between the office chairs.

The table above indicates the dimensions of the different structures of the office chairs. The main modifications to the “Jazz” chair were done on the seat length (anterior and posterior), armrest height, cushion depth, lumbar support height and edge of lumbar support height/area for the buttocks. The redesigned office chair was adjusted as well as possible to suit the anthropometric dimensions of the South African sample that had been collected.

Seat length was originally 430mm. Three seat lengths were constructed to produce a length of 470mm, 530mm and 590mm (see Figure 24, B). The seat depth posterior was originally 20mm and the redesigned office chair was modified to provide a 70mm seat depth posterior. The armrest height for the original office chair was set at 240mm and the redesigned armrests were designed to allow the armrests range between a minimum of 80mm to a maximum heigth of 330mm (see Figure 24, C).

The cushion depth was modified from 40mm, which was set for the original office chair, to 50mm anteriorly and 30mm posteriorly for the redesigned office chair (see Figure 24, A). The lumbar support height ranged from 120mm to 220mm for the original office chair and 150mm to 260mm for the redesigned office chair. The redesigned office chair allowed for a greater area for the buttocks, with the edge of the lumbar support ranging between 110mm to 230mm, while the original office chair edge of lumbar support had ranged between 0mm to 80mm.

Figure 37: The main office chair modifications (A - Lumbar support height, B - Seat pan length and C – Armrests)**.**

The figure above indicates the main modifications that were done to the “Jazz” medium back chair. The lumbar support height, seat depth anterior and posterior and armrests all needed to be adjusted to suit the anthropometry of the total South African sample. The pictures of the office chair structures were taken in the most suitable way to illustration the main adjustments that were made.

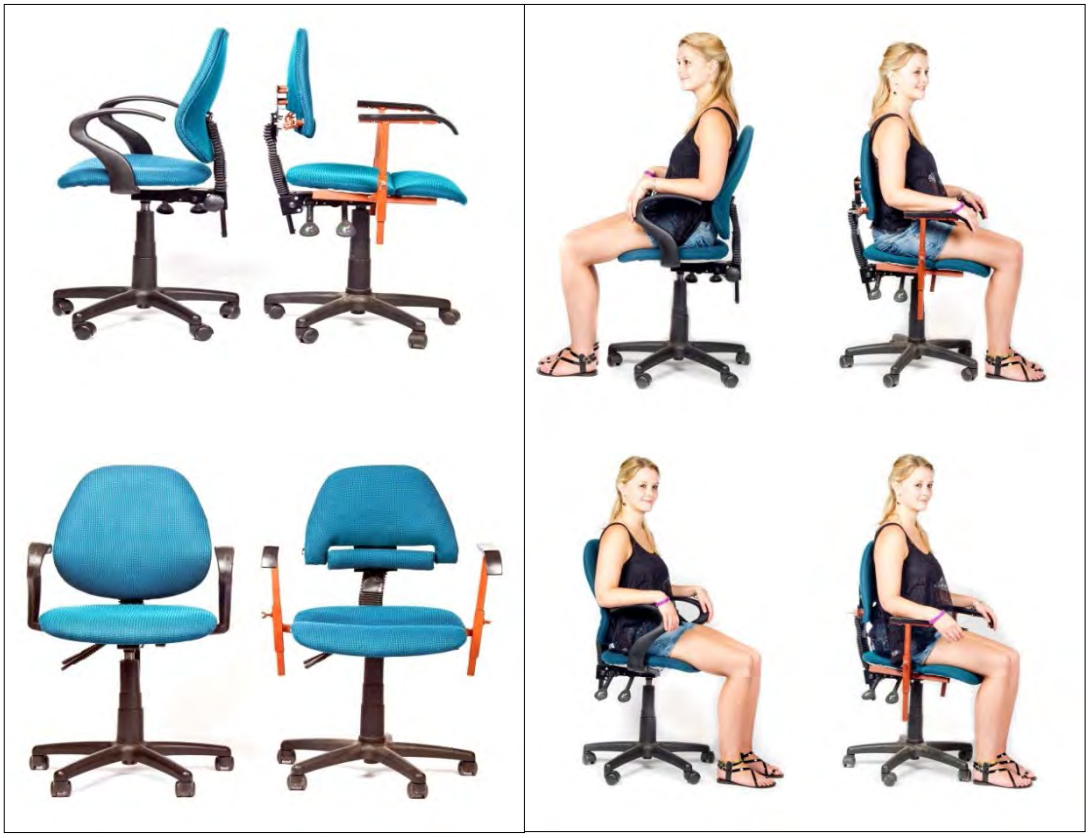

Figure 38: Comparison of the original office chair and the redesigned office chair. (The “Jazz” medium back office chair is situated on the left and the redesigned office chair is on the right).

COMPARING ORIGINAL OFFICE CHAIR DIMENSIONS TO CURRENT SOUTH AFRICAN ANTHROPOMETRIC CHAIR DIMENSIONS

The “Jazz” medium back office chair dimensions were compared to the South African sample dimensions. This allowed for the comparison of the current office chair dimensions to that of the South African sample and to identify the main modifications that would need to be altered to ensure the office chair accommodates the South African chair dimensions.

Table XXIV: Comparing the original office chair dimensions to those obtained from the South African sample.

		Current study		
Office Chair Structures	**Original office chair: “Jazz”**	**Total South African sample**	**Female Sample**	**Male sample**
Seat Width (mm)	480	560	580	520
Seat Length (mm)	430	460	460	460
Seat Depth Posterior (mm)	20	70	70	50
Seat Height Minimum (mm)	440	360	350	400
Seat Height Maximum (mm)	560	470	447	480
Armrest Height Minimum (mm)	240	145	150	140
Armrest Height Maximum (mm)	240	235	234	240
Armrest Length (mm)	260	250	240	260
Backrest Height Minimum (mm)	470	420	420	430
Backrest Height Maximum (mm)	550	470	470	490
Backrest Width (mm)	440	460	480	440
Cushion Depth (mm)	40	60	60	60
Lumbar Support Height Minimum (mm)	120	150	150	140
Lumbar Support Height Maximum (mm)	220	250	260	220
Edge of Lumbar Support Height Minimum (mm)	0	100	120	110
Edge of Lumbar Support Height Maximum (mm)	80	180	230	190

Total sample of the South African population (n=683), female sample (n=448) and total male sample (n= 235). Dark shaded areas represent a difference of 40 mm.

Table XXIV indicates the main differences in the office chair dimensions of an office chair currently on the market and the office chair dimensions that were collected. The main differences between the original office chair and chair that was constructed

based on the current study were the seat width, seat height, seat length, armrest height, backrest height, lumbar support height and the edge of lumbar support height: 40mm and greater differences resulted between these dimensions.

Table XXV: Percentiles of the South African anthropometric office chair dimensions related to the original office chair dimensions.

		Current Study											
Office chair structures	**Original office chair: "Jazz"**	**Current study office chair percentiles**	**Total sample**	**Female sample**	**Male sample**	**Black Female sample**	**White Female sample**	**Coloured Female Sample**	**Indian/ Asian Female Sample**	**Black Male sample**	**White Male sample**	**Coloured Male sample**	**Indian/ Asian Male Sample**
Seat Width (mm)	480	95th%ile	68th%ile	59th%ile	68th%ile	58th%ile	72nd%ile	76th%ile	83rd%ile	87th%ile	76th%ile	88th%ile	82nd%ile
Seat Length (mm)	430	5th%ile	0.7th%ile	0.8th%ile	0.4th%ile	0.7th%ile	None	None	2nd%ile	0.3rd%ile	None	None	None
Seat Depth Posterior (mm)	20	95th%ile	31st %ile	18th%ile	31st %ile	14th%ile	23rd%ile	26th%ile	20th%ile	56th%ile	57th%ile	59th%ile	29th%ile
Seat Minimum Height (mm)	440	5th%ile	83rd%ile	95th%ile	83rd%ile	98th%ile	81st%ile	94th%ile	94th%ile	63rd%ile	48th%ile	76th%ile	64th%ile
Seat Maximum Height (mm)	560	95th%ile	All	All	All	All	All	All	All	All	All	All	All
Armrest Minimum Height (mm)	240	5th%ile	97th%ile	98th%ile	97th%ile	99th%ile	96th%ile	97th%ile	97th%ile	98th%ile	93rd%ile	96th%ile	All
Armrest Maximum Height (mm)	240	95th%ile	97th%ile	98th%ile	97th%ile	99th%ile	96th%ile	97th%ile	97th%ile	98th%	93rd%ile	96th%ile	All
Armrest Length (mm)	260	50th%ile	70th%ile	89th%ile	79th%ile	88th%ile	93rd%ile	95th%ile	88th%ile	56th%ile	53rd%ile	84th%ile	69th%ile
Backrest Height Minimum (mm)	470	5th%ile	51st %ile	59th%ile	51st%ile	65th%ile	34th%ile	55th%ile	83rd%ile	51st%ile	2nd%ile	56th%ile	29th%ile
Backrest Height Maximum (mm)	550	95th%ile	96th%ile	All	96th%ile	99th%ile	98th%ile	97th%ile	All	96th%ile	79th%ile	All	94th%ile
Backrest Width (mm)	440	50th%ile	38th%ile	29th%ile	38th%ile	26th%ile	34th%ile	44th%ile	50th%ile	63rd%ile	32nd%ile	68th%ile	41st%ile
Cushion Depth(mm)	40	50th%ile	13th%ile	9th%ile	13th%ile	13th%ile	18th%ile	19th%ile	12th%ile	12th%ile	24th%ile	33rd%ile	23rd%ile
Lumbar Support Height Minimum (mm)	120	5th%ile	0.2nd%ile	None	0.4nd%ile	None	0.1st%ile	None	None	None	None	None	None
Lumbar Support Height Maximum (mm)	220	95th%ile	84th%ile	78th%ile	84th%ile	69th%ile	94th%ile	All	96th%ile	All	93rd%ile	All	All
Edge of Lumbar Support Height Minimum (mm)	0	5th%ile	None	None	None	None	None	None	None	None	None	None	None
Edge of Lumbar Support Height Maximum (mm)	80	95th%ile	None	None	None	None	None	9th%ile	27th%ile	None	None	None	None

Total percentiles of the South African sample (n=683). The dark shaded area represents a ±15%ile difference between the chair percentiles.

The “Jazz” medium back office chair had a seat width of 480mm, while the current study had a 95th%ile for seat width (560mm). The “Jazz” chair had a seat width that only accommodated the 68th%ile of the total South African sample, 59th%ile of the total female sample and 68th%ile of the total male sample. The seat width was too narrow for the female groups except for the Indian/Asian female group and the Black, Coloured and Indian/Asian male groups.

The seat length (430mm) of the “Jazz” chair was too short for the South African sample. The 5th%ile (460mm) was chosen for the current study and only 0.7th%ile of the South African sample was accommodated, therefore, 99.3% of the South African sample would not be accommodated.

The seat depth posterior for the “Jazz” chair was 20mm and the 95th%ile (70mm) was chosen in order to accommodate for the South African sample; however, only the 31st%ile of the total South African sample was accommodated with a 20mm seat depth posterior.

The minimum seat height of the "Jazz" chair was 440mm and a 5th%ile (360mm) was selected for seat minimum height for the current study. The “Jazz” seat minimum seat height accommodated the 83rd%ile of the total South African sample, therefore indicating that the minimum seat height was actually too high for the sample. The “Jazz” maximum seat height (560mm) accommodated the total South African sample.

The armrest minimum height (240mm) of the “Jazz” office chair accommodated the 97th%ile of the total South African sample, whereas the minimum height should accommodate the 5th%ile (145mm). The “Jazz” chair’s maximum armrest height (240mm) accommodated the 97th%ile of the total South African sample and the current study selected 95th%ile (235mm) for the maximum armrest height. The maximum armrest height accommodated the South African sample however; the minimum armrest height was too high.

The 50th%ile (250mm) was selected for armrest length for the current study and the “Jazz” chair had an armrest length of 260mm. The armrest length was too long for the total South African sample (70th%ile); however, it did accommodate the Black male group (56th%ile), White male group (53rd%ile) and Indian/Asian male group (69th%ile).

The 5th%ile (420mm) for the backrest minimum height was chosen for the current study and the “Jazz” chair had a minimum height of 470mm. The “Jazz” chair’s

backrest minimum height accommodated the 51st%ile of the South African sample, indicating that the backrest height was too high for the sample. The only ethnic group that was accommodated by the “Jazz” backrest height was the White male sample (2nd%ile).

The “Jazz” chair’s maximum backrest height (550mm) accommodated the 96th%ile of the total South African sample. The current study selected a maximum backrest height of 550mm (95th%ile). The White male sample was the only ethnic group that was of some concern since the backrest maximum height accommodated the 79th%ile.

The current study selected 50th%ile (380mm) for backrest width and the Jazz backrest width (440mm) accommodated the 38th%ile of the total sample. The Jazz backrest width was slightly too narrow for the female sample, the Black female group and White female group and also the White male group, however, it was slightly too wide for the Coloured male group. The cushion depth (40mm) of the Jazz chair accommodated the 13th%ile of the total sample and the ideal cushion depth should have accommodated the 50th%ile (60mm).

The minimum lumbar support height of the Jazz chair accommodated the 0.2nd%ile of the total sample and the ideal minimum lumbar support height should accommodate the 5th%ile (150mm). The 95ht%ile (250mm) was chosen for the maximum lumbar support height for the current study and the “Jazz” chair’s maximum lumbar support height (220mm) accommodated the 84th%ile of the total sample; however, only the 69th%ile of the Black female group was accommodated. This indicates that the Black female group would need a larger area for the buttocks.

The minimum (0mm) and maximum (80mm) edge of lumbar support height of the “Jazz” office chair did not accommodate the South African sample. A larger area for the buttocks would be needed for the South African sample.

A number of structural dimensions on the “Jazz” office chair would need to be modified to suit the South African sample dimensions. The main modifications would need to done to the seat width as the current width is too narrow, especially for the Black female sample; seat length anterior and posterior would need to be longer; the seat minimum height and the armrest minimum height would need to be much shorter for the South African sample; and a larger lumbar support height and edge of

lumbar support height would need to be implemented to accommodate for the buttocks area, especially for the Black female sample.

CHAPTER V

DISCUSSION

INTRODUCTION

This study was aimed at collecting anthropometric data to supply guidelines for office chair manufacturers to produce an office chair suited to South African dimensions. This study also compared the anthropometric (participant and chair) dimensions of each ethnic group (Black, White, Coloured and Indian/Asian) of the South African population. The South African sample variables were compared to the measurements of a current office chair as well as variables available from other countries. The anthropometric measures included stature, shoulder height, body mass, body mass index, waist circumference, hip circumference and waist to hip ratio. The chair measures included seat height, seat depth anterior, seat depth posterior, seat width, backrest height, backrest width, backrest point, cushion depth, lumbar support height, edge of lumbar support height, lumbar support point, armrest height and armrest length.

ANTHROPOMETRIC DIFFERENCES OBSERVED IN SAMPLE

STATURE

Stature was measured using a standard 1.5m dressmaker's tape measure, which was attached to the floor and wall. Stature was measured from the floor to the apex of the individual while standing upright against a wall. South African males had a significantly greater ($p<0.01$) stature compared to the female groups. The average stature for the male sample was 1745.23±87.55mm and the female's average stature was 1624.22±71.48mm. Onuoha et al. (2012) also stated that South-Eastern males (163.40±5.84cm) had a greater stature compared to the South-Eastern females (156.80±5.28cm). Kroemer (2009) stated that, in a study done in 20 regions worldwide, the average male stature was greater than the average stature for females.

SHOULDER HEIGHT

Shoulder height was measured using a metal adjustable ruler. Shoulder height was measured from the floor to the acromion process of the participant while they stood upright against a wall. Shoulder height expectedly reflected the same trend that was observed for stature. The male sample had a greater average shoulder height (1420±68mm) compared to the female sample shoulder height (1319±60mm, a 101mm difference). Kroemer (2009) stated that of 681 Russian students, the males had a greater average shoulder height (1440±54mm) compared to the female students (1334±54mm, a difference of 106mm). The White females (1368.44±51.43mm) had the greatest shoulder height of the total female sample and the White males (1461.77±59.50mm) had the greatest shoulder height in the South African sample.

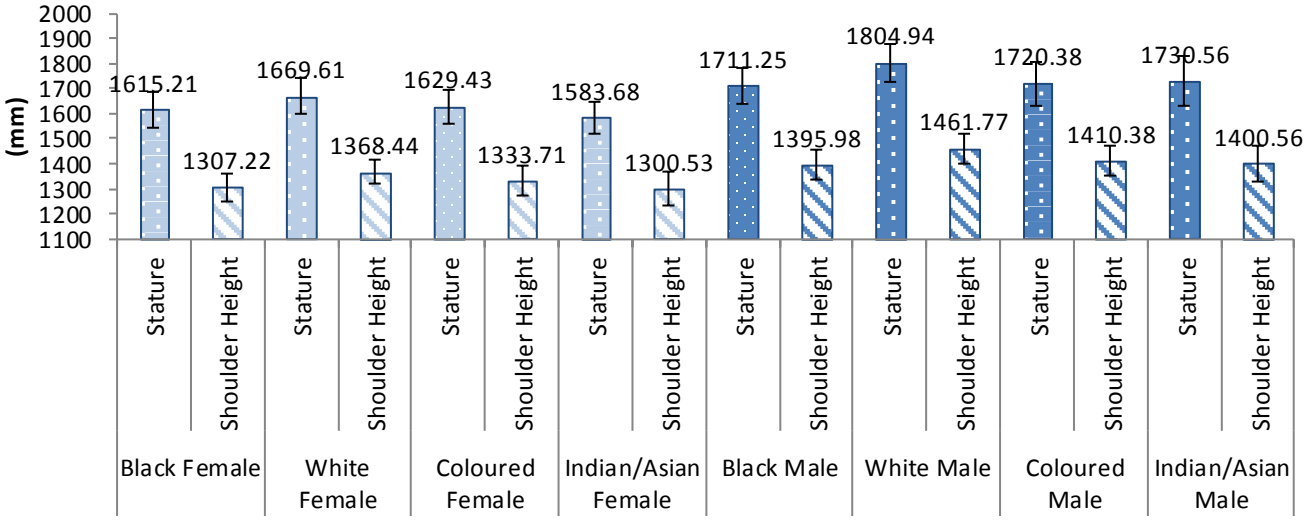

Figure 39: Stature and shoulder height of the South African ethnic groups

BODY MASS

Body mass was recorded using a commercial bathroom scale. The participants removed all heavy clothes and shoes before being measured. The South African male sample (82.40±17.60kg) had a greater average mass compared to the females (78.30±20.38kg). Only a slight difference of 4.1kg was observed for the mean mass

for sex. The trend also occurred for the south-eastern Nigerian population; the males (56.70±7.14kg) had a greater mass compared to the females (51.30±4.91kg) (Onuoha *et al.,* 2012). United States males also had a greater body mass (87kg) compared to the female United States average body mass (75kg) (Kroemer, 2009). This also indicates that the South African population had a greater mass compared to the south-eastern Nigerians (25.70kg difference for the males and 27kg difference for the females) but similar body mass trends of the United States population. These body mass differences are not unique to the South African sample; therefore chair design should be incorporating population differences worldwide.

The White males overall had the greatest body mass (90.0±15.9kg) compared to all the other groups. In conjunction with this, the White males had the greatest waist and hip circumference and seat width compared to the other male sample groups. The Black female (79.98±20.20kg) sample had the greatest mass in the female sample (White, Coloured and Indian/Asian). This resulted in the Black female sample reflecting the greatest waist and hip circumference and therefore seat width compared to the other South African, female ethnic samples.

BODY MASS INDEX

The average body mass index for the male sample was 27.2±5.8kg.m^{-2} and the average body mass index for the female sample was 29.7±7.6 kg.m^{-2}. The White males (28.15±5.77kg.m^{-2}) had the greatest BMI recordings compared to the other male samples. The Black female sample (30.66±7.41kg.m^{-2}) presented with the highest average BMI reading compared to the other female and male samples. More than half the Black female sample was overweight or obese (BMI>25kg.m^{-2}). Puoane et al. (2002) also found that the female sample had the greater BMI value compared to the male sample.

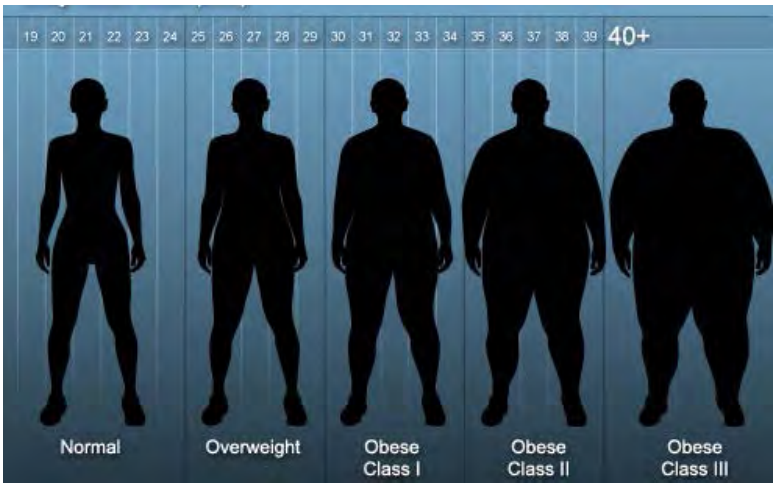

Figure 40: The silhouettes range from underweight (BMI < 20) to highly severe obesity (BMI > 40) (Taken from Ralph, 2011).

The figure above indicates the BMI range from underweight to overweight. The average male sample and female sample BMI is bordering on obesity. The average White males fall in the category “overweight”, while the Black females fall in the “obese” category. This will affect the design of office chairs as the specific structures that support the body would need to increase in size and strength in order to support the increasing body weight of the South African sample and specific ethnic groups.

WAIST CIRCUMFERENCE

Waist circumference was measured with a standard 1.5m dressmaker’s tape measure. Waist circumference was measured above the hip bone around the abdomen. The South African male sample had a slightly greater waist circumference compared to the female sample (6mm difference). This indicated that males had a slightly greater fat distribution around their abdomen and this would result in a greater concern related to health risks such as type 2 diabetes, cardiovascular diseases and strokes (Janssen *et al.* 2004). The female sample had a greater fat distribution around their buttocks and this will influence the office chair structures such as lumbar support height, seat depth posterior and seat width. Onuoha *et al.,* (2010) conducted a study on Nigerian agricultural farm workers, 200 females and 300 males. It was found that the female sample had the greater waist circumference compared to the male sample.

HIP CIRCUMFERENCE

Hip circumference was also recorded using a standard 1.5m dressmaker's tape measure. Hip circumference was measured around the largest area of the buttocks. There was a significant difference ($p<0.01$) between sex for hip circumference. As expected, the female sample would have a greater hip circumference (1128±155mm) compared to the male sample hip circumference (1052±113mm, mean difference of 76mm). The Black female sample had a significantly ($p<0.05$) greater, average hip circumference (114.93±15.12cm) compared to the other ethnic groups. Onuoha et al. (2012) also found that the female sample had a greater hip circumference compared to the male sample. This has implications for office chair design as the seat width would need to accommodate a larger hip circumference and the lumbar support height and edge of lumbar support height would need to be adjusted to accommodate a larger buttocks area.

WAIST TO HIP RATIO

A significant difference ($p<0.01$) was observed for sex. The male samples had a greater WHR compared to the female sample groups. This indicates that males distribute most of their fat around their waists and that females distribute most of their fat around their hips, such as is observed with the Black female sample. Therefore males are more susceptible to chronic diseases such as type 2 diabetes, cardiovascular diseases (CVD) and strokes (Janssen *et al.,* 2004).

DIFFERENCES OBTAINED FOR ANTHROPOMETRIC CHAIR DIMENSIONS

SEAT PAN MEASUREMENTS

SEAT HEIGHT

Seat height was taken from the floor to the popliteal of the participant while seated and maintaining a 90 degree knee angle. The male sample had a greater average seat height (440±26mm) than the female sample (394±28mm). This indicated that the South African male sample had a popliteal height greater than the South African female sample. A study done by Onuoha et al. (2012) looked at the south-eastern Nigerian males and females. The "Jazz" medium back office chair's height ranged from 440mm to 560mm and the South African sample seat height dimension ranged from 360mm to 470mm. The "Jazz" chair did not accommodate the shorter individuals in the South African sample. The south-eastern males also had a greater seat height compared to the south-eastern females (difference of 39mm). Kroemer (2009) also stated that the male Russian students and Taiwanese males had a greater seat height (468±24mm and 411±19mm respectively) compared with the Russian females and Taiwanese females (423±23mm and 379±18mm respectively).

Abrahamyan et al. (2008) found that there was a strong correlation between femur length and tibia length for males (R^2=0.97) and females (R^2=0.94). Femur length is also a strong predictor of stature and therefore, the taller the individual, the longer the femur length (upper leg length) and, furthermore, the longer the tibia length (lower leg length). This study indicated a weak correlation between stature and seat anterior (R^2=0.43) as well as a weak correlation between seat height and seat anterior (R^2=0.36); however, there was a strong correlation between stature and seat height (R^2=0.73). The White male and White female sample had the greatest stature and therefore also the greatest seat height within sex groups. The seat height must be adjustable to suit different users as if the seat height that is too high for a user, discomfort will result due to lack of blood circulation to the lower limbs, increased pressure on the underside of the thigh and pressure on the popliteal (Kroemer and Grandjean, 1997).

SEAT DEPTH ANTERIOR

Seat depth anterior was the horizontal distance on the seat pan, from the popliteal to the vertical line of the lumbar support feature. The male sample had a greater seat depth anterior (522±35mm) compared to the female sample (510±30mm). Onuoha et al. (2012) also found this trend. Abrahamyan et al. (2008) stated that there is a strong correlation between stature and femur length for males (R^2=0.90) and females (R^2=0.92). The male sample had a significantly ($p<0.01$) greater stature compared to the female sample and therefore had a greater seat depth anterior. There was no significant difference within sex groups.

SEAT DEPTH POSTERIOR

Seat depth posterior was the horizontal distance on the seat pan from the vertical line of the lumbar support to the posterior aspect of the buttocks. A significant difference was observed for sex ($p<0.01$). Seat depth posterior is sex specific; it was observed that the total female sample (70±16mm) had a greater seat depth posterior compared to the total male sample (50±13mm). The Black female sample (70±16mm) had the greatest seat depth posterior for the total sample and they also had the greatest hip circumference (1149±151mm). A greater hip circumference indicates that the fat distribution is situated around the buttocks (Janssen *et al.,* 2004). Posterior seat depth would have to be considered for chairs designed specifically for use by the unique South African population.

SEAT WIDTH

Seat width was the width of the hips while the participant was seated. A significant difference was observed between sexes ($p<0.01$). Within the male sample, the only significant difference ($p<0.05$) was between the Black males and White males. The White males (470±40mm) had a greater seat width compared to the Black males (435±49mm). The Black females (487±60mm) had the greatest seat width overall and the Indian/Asian females (449±65mm) had the smallest, mean seat width overall. Onuoha et al. (2012) also found that the females had a greater seat width compared to the male sample. This indicates that seat width also needs to be sex specific.

Ideally the seat width of office chairs would need to be larger to accommodate the larger individuals in the South African sample and, in so doing, will also accommodate the smaller individuals.

BACKREST MEASUREMENTS

BACKREST HEIGHT

Backrest height was measured with a plastic ruler, vertically from the seat pan to the scapula of the participant, while seated. A significant difference ($p<0.01$) for backrest height requirement was observed for sex. The White females (448±35mm) had a significantly greater ($p<0.05$) backrest height requirement compared to the Black females (464±31mm) and Indian/Asian females (453±34mm). The White males (530±40mm) had a significantly greater ($p<0.01$) backrest height compared to the Black males (479±40mm) and Coloured males (473±33mm). A higher backrest height would be needed to accommodate the White males as they had the greatest backrest height overall. The backrest and form of the backrest supports the upper body and prevents the back muscles from fatiguing (Kroemer and Grandjean, 1997); therefore the backrest height of office chairs would need to have a greater adjustment range (420mm to 550mm) to suit the South African sample.

BACKREST WIDTH

Backrest width was the participant's back breath and was measured with a plastic ruler. A significant difference ($p<0.01$) was observed between the sexes for backrest width. The Black females had the greatest backrest width measurement overall. Openshaw and Taylor (2006), state that the backrest width is the same measure as hip breath (seat width). The Black females had the greatest seat width of the total female sample and therefore required the largest backrest width (487±60mm). The White males had the largest seat width and this resulted in the White males having the largest backrest width (470±40mm) within the male sample. The medium back "Jazz" office chair had a 440mm backrest width which would not be sufficient to support the Black female sample, White female sample, White male sample and the Coloured male sample. Kroemer (2009) stated that a greater shoulder breadth was observed for the male Russian students (416±23mm) compared to the female

Russian students (412±21mm), however, this was only a slight difference of 4mm whereas the current study indicated a greater difference of 60mm for the female sample.

BACKREST POINT

Backrest point is the vertical line from the backrest support to the seat pan and it is the distance measured from the front edge of the seat pan to the vertical point. The difference in backrest point and lumbar support point determines the cushion depth, which is significant in supporting the back and lumbar region. No significant difference was observed for backrest point for sex. However, the total male group had a slightly longer average backrest point (580±35mm) compared to the total female sample (575±32mm). This is also due to the fact that the total male sample had a greater anterior seat depth (522±35mm) compared to the total female sample group (50.99±3.03cm). The longer upper leg length will result in a more posterior backrest point.

CUSHION DEPTH

The cushion depth is the difference between the backrest point and lumbar support point. The cushion depth is the area between the backrest point and lumbar support point and it provides support for the back and lumbar region. No significant difference was observed for sex. The average cushion thickness for the total male sample (58±20mm) was similar to the total female sample cushion thickness (65±18mm). The Black females (63±25mm) had a slightly larger cushion depth compared to the other groups. This is due to the fact that the Black females had a greater difference in lumbar support point and backrest point.

LUMBAR SUPPORT MEASUREMENTS

LUMBAR SUPPORT HEIGHT

Lumbar support height is the vertical height from the seat pan to the midpoint of the lumbar support, which was placed over the 2nd to 5th vertebra. Significant difference ($p<0.01$) for lumbar support was obtained for sex. The average lumbar support height for the Black female sample (210±30mm) was significantly ($p<0.01$) greater than the White female sample (187±24mm), Coloured female sample (166±20mm) and Indian/Asian female sample (173±29mm). The Black female sample also had the greatest hip circumference (1149±151mm) in the total sample and therefore resulted in the greatest lumbar support height in order to accommodate for the buttocks area. The White male sample (176±23mm) had the largest lumbar support height for the total male sample and was significantly ($p<0.01$) larger than the Black male group (169±20mm). The White males also had the largest hip circumference in the total male sample (1077±97mm) and therefore resulted in the larger lumbar support height in order to accommodate for the buttocks area while seated. The Black female sample had the greatest lumbar support measurement overall. This indicates that a specialised office chair would need to be manufactured especially for the Black female sample, in order to support the buttocks. About 80 percent of adults will experience lower back pain due to the incorrect seating and insufficient support of the lumbar structures of an office chair (Kroemer and Grandjean, 1997).

The lumbar support is typically attached to the backrest and by adjusting the lumbar support, the backrest will be adjusted accordingly. The medium back, “Jazz” office chair has a lumbar support that adjusts between 120mm to 220mm, however a greater adjustment would need to be implemented for the South African sample. The lumbar support height and the edge of lumbar support height are imperative in order to maintain the natural curve of the spine while sitting and to reduce discomfort.

EDGE OF LUMBAR SUPPORT HEIGHT

The edge of the lumbar support height was the vertical line, measured from the seat pan to the inferior edge of the lumbar support. A similar trend was observed for lumbar support height. The edge of lumbar support height measurements indicated a significant difference ($p<0.01$) between the sexes. Within the female sample, the Black females (180±30mm) had a significantly ($p<0.01$) greater edge of lumbar support height compared to the White females (157±24mm), Coloured females (136±20mm) and Indian/Asian females (143±29mm). The White males had a greater edge of lumbar support (146±23mm) for the total males sample and a significantly ($p<0.01$) greater edge of lumbar support height compared to the Black males (139±20mm). The Black females had a significantly ($p<0.01$) greater edge of lumbar support height for the total South African sample. This therefore indicates that Black females have the largest buttocks and therefore need a specialised office chair incorporating a buttocks area/space specifically for this ethnic group.

LUMBAR SUPPORT POINT

The lumbar support point was the vertical point from the lumbar support to the seat pan and then measured from that point to the anterior aspect of the seat pan. The difference between lumbar support point and backrest point indicates the cushion depth needed to support the back and lumbar region while seated. No significant difference was observed for lumbar support point and sex. No significant difference was observed among the male sample (522±35mm average) and female sample (510±30mm average).

ARMREST MEASURES

ARMREST HEIGHT

The vertical distance from the seat pan to the elbow was measured as the armrest height. Armrest height did not indicated a significant difference ($p<0.01$) for sex. The total female sample (191±27mm) had a slightly higher average armrest height

compared to the total male sample (186±31mm). The White females (200±25mm) had the greatest armrest height for the total female sample and the White males (200±30mm) had the largest armrest height compared to the other male groups. The White males also had a significantly ($p<0.01$) greater armrest height compared to the Black males (175±29mm). Onuoha et al. (2012) found the opposite with elbow rest height (armrest height). The male sample had a greater height (24.30±3.70cm) compared to the female sample (17.9±1.44cm), with a mean difference of 6.40cm. The armrest ideally should range in height as it should fit the individual and allow for adequate support. The armrests reduce static loading and stress on the neck and shoulder girdle; therefore it is imperative that the armrests are adjustable to suit the user (Pheasant and Haslegrave, 2006).

ARMREST LENGTH

Armrest length was measured from the participants wrist to the elbow, positioned at 90 degrees. Armrest length reflected a significant ($p<0.01$) difference for sex. The total male sample (259±23mm) had a greater average armrest length compared to the total female sample (248±10mm). There were no significant differences within the female and male groups indicating that females had similar armrest lengths and males had similar armrest lengths. This was also a finding in a study done by Onuoha et al. (2012). They found that the males had a greater arm length compared to the female sample by a mean difference of 61mm. Onuoha et al. (2012) reflected the same trend; however, the current study's armrest length was greater. An armrest that is too long will result in the individual being further from the desk and keyboard, resulting in the individual stretching the arms to make contact with the keyboard. This will result in discomfort of the arms and shoulder girdle. An armrest length which is too short will not provide adequate support for the arm (Pheasant and Haslegrave, 2006).

COMPARISON OF THE ORIGINAL OFFICE CHAIR DIMENSIONS AND THE ANTHROPOMETRIC OFFICE CHAIR DIMENSIONS FOR THE SOUTH AFRICAN SAMPLE

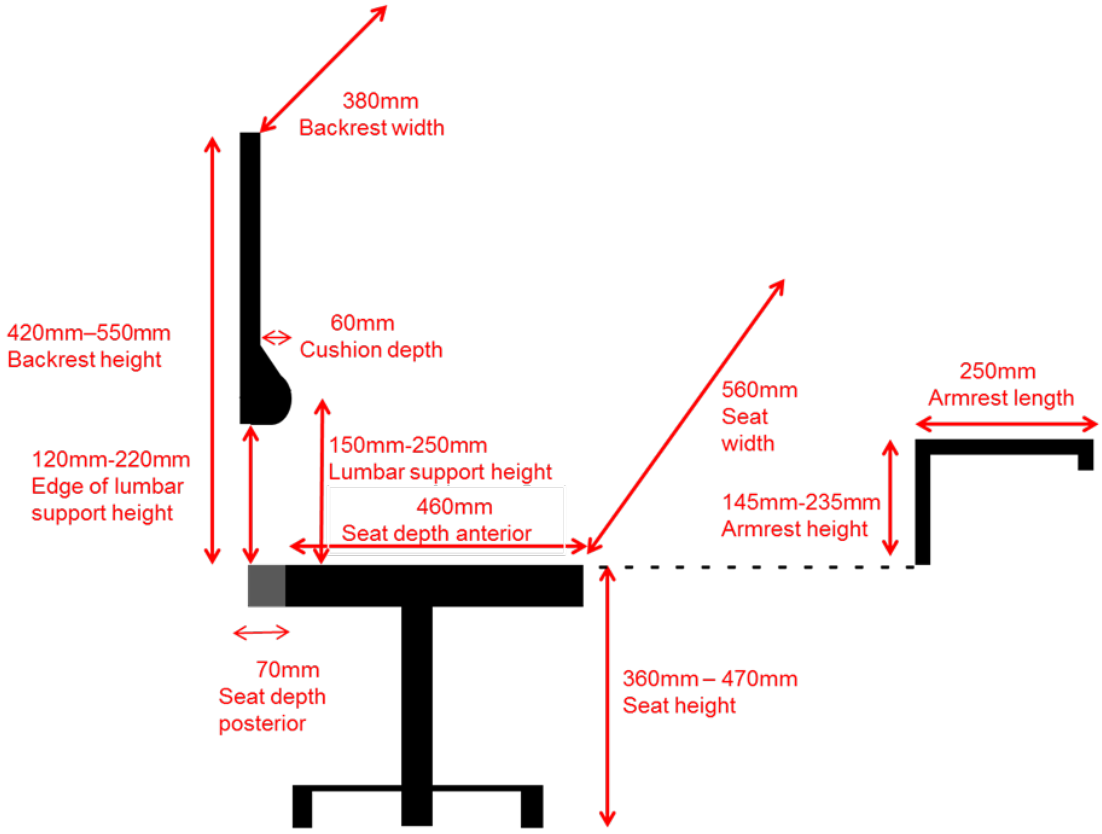

Figure 41: Anthropometric office chair dimensions of the total South African sample (n= 683).

(Refer to Table XXVI, in Results section, page 85)

Seat height should ideally adjust between 360mm to 470mm to accommodate the 5th%ile to the 95th%ile; seat depth anterior should accommodate the 5th%ile, 460mm and seat depth posterior should accommodate the 95th%ile, 70mm for an office chair for the total South African sample. The seat height of the "Jazz" office chair would be too high for the total South African sample; the seat length as well as the seat depth posterior are slightly too short for the South African sample. Seat width should ideally accommodate the 95th%ile (560mm), however, only the 68th%ile of the South African sample were accommodated, indicating that the seat width is too narrow.

Backrest height should accommodate the 5th%ile to 95th%ile (420mm to 550mm) and the backrest width should accommodate the 50th%ile (380mm). The backrest minimum height was too high to support the South African sample however; the backrest maximum height and backrest width accommodated the sample (96th%ile and 38th%ile respectively). The armrest height should ideally adjust between the 5th%ile to 95th%ile (145mm to 235mm) and armrest length should accommodate the 50th%ile (250mm) however, the armrest height of "Jazz" office chair was set at 240mm and this did not accommodate the 5th%ile of the South African sample as well as the armrest length being too long.

Ideally, the 5th%ile to 95th%ile (150mm to 250mm) should be the adjustable range of the lumbar support height and the edge of the lumbar support should also adjust to accommodate the 5th%ile to 95th%ile (120mm to 220mm). The lumbar support of the "Jazz" office chair did support the South African sample's dimensions; however the edge of the lumbar support did not, as inadequate space for the buttocks was provided.

The backrest point and lumbar support point should accommodate the 50th%ile (580mm and 510mm respectively). The cushion, which is the space between the lumbar support and backrest support, should be 60mm in depth. The cushion depth of the "Jazz" office chair did not accommodate the cushion depth required for the total South African sample.

From data obtained during this study with a representative South African sample (n=683) is appears clear that current office chair designs accommodate only a small percentage of the sample. It is observed that while most male users are accommodated by the current design dimensions, the majority of female users experience discomfort at best, and at worst are put at risk of developing lower body and spine-related musculo-skeletal disorders.

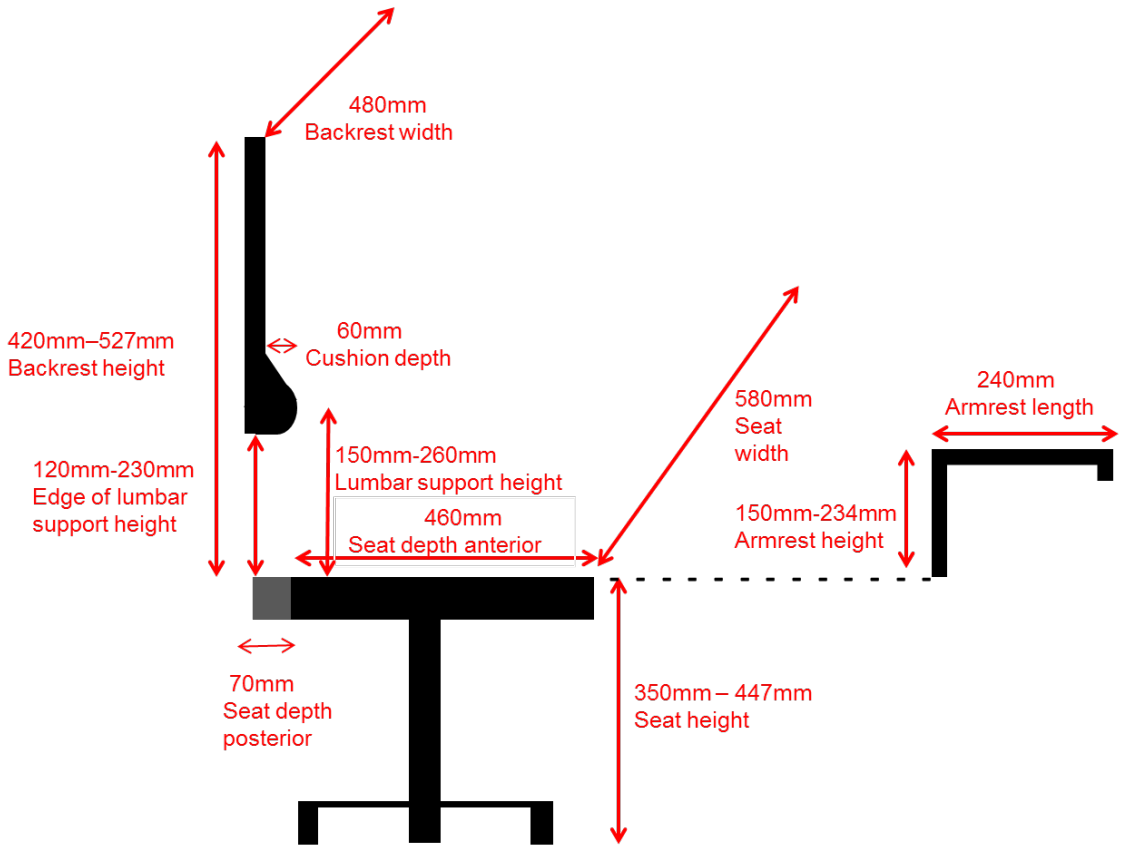

Figure 42: Anthropometric office chair dimensions of the total female sample (n= 448).

(Refer to Table XXVII, in Results section, page 85)

An office chair's seat height should ideally be adjustable between the 5th%ile and the 95th%ile (350mm to 447mm); seat depth anterior should accommodate the 5th%ile (460mm) and seat depth posterior should accommodate the 95th%ile (70mm), in order to suit the total female sample. The "Jazz" office chair's seat height was too great; the seat depth anterior was slightly too short and the seat depth posterior was too small to support the buttocks of the total female sample. Seat width should ideally accommodate the 95th%ile (580mm); however the seat width of the "Jazz" chair only accommodated the 59th%ile of the total female sample, indicating that the seat was too narrow. This data clearly illustrates that a wider/larger seat pan is required in chair design to ensure comfort as well as to reduce sitting-related risk.

The backrest height should ideally adjust to accommodate the 5th%ile to 95th%ile (420mm to 527mm) and the 50th%ile (480mm) backrest width should accommodate

the total female sample. The minimum backrest height of the “Jazz” office chair was too great for the female sample and the backrest width was too narrow.

Armrest height should adjust to accommodate the 5th%ile to 95th%ile (150mm to 234mm) and armrest length should accommodate the 50th%ile (240mm) for the female sample. Due to the fact that the “Jazz” office chair armrest height was set, it only accommodated the 98th%ile and therefore was too high for many of the South African females, as well as the length of the armrest being too long.

Lumbar support height should adjust to accommodate the 5th%ile to 95th%ile (150mm to 260mm) and the edge of the lumbar support should also adjust to accommodate the 5th%ile to 95th%ile (120mm to 230mm); however the lumbar support height and the edge of the lumbar support height did not accommodate the female sample due to the fact that more space for the buttocks is needed for the female sample.

The backrest point and lumbar support point should accommodate the 50th%ile (580mm and 510mm respectively). The cushion, which is the space between the lumbar support and backrest support, should be 60mm in depth. Only the 9th%ile cushion depth accommodated the female sample.

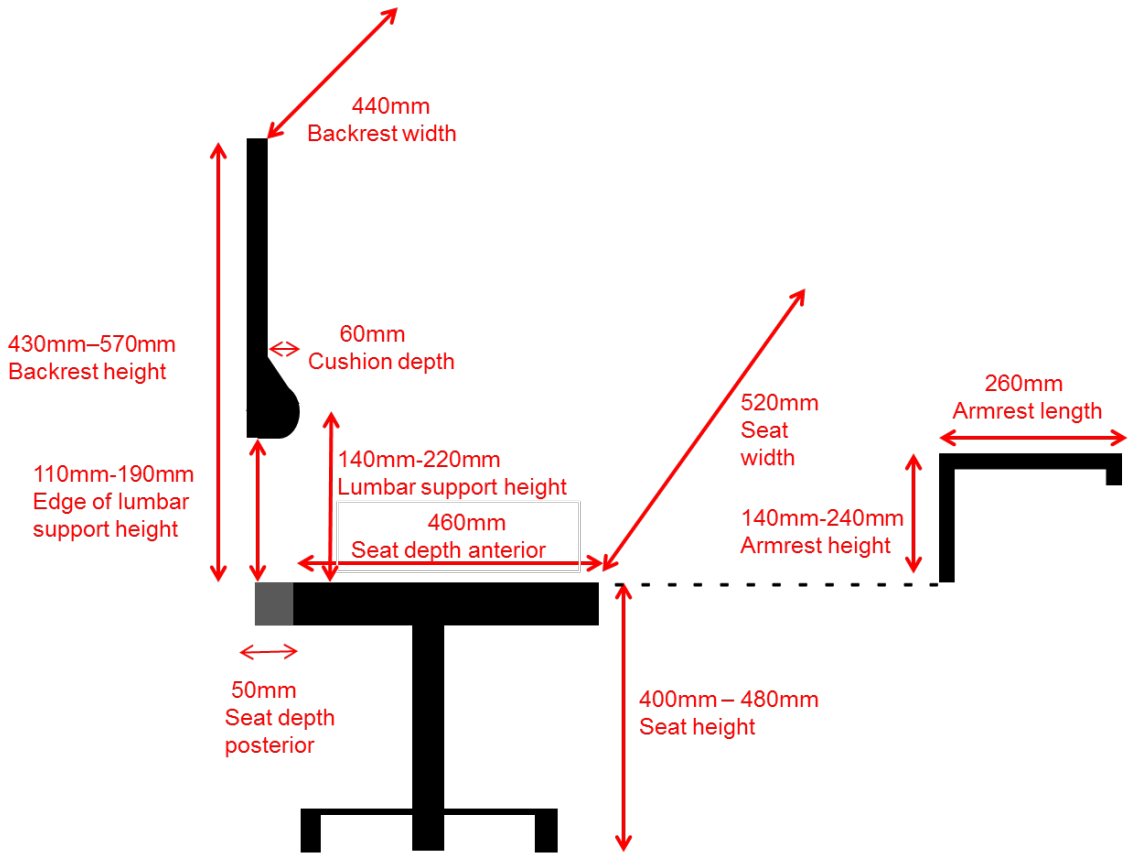

Figure 43: Anthropometric office chair dimensions of the total male sample (n= 235).

(Refer to Table XXVIII, in Results section, page 85)

Ideally, the total male sample should have a seat height that is adjustable between the 5th%ile to the 95th%ile (400mm to 480mm); 5th%ile (460mm) seat depth anterior and a seat depth posterior to accommodate the 95th%ile (50mm). The "Jazz" office chair's minimum seat height (440mm) was too high for the male sample, while the seat depth anterior and the seat depth posterior were too short. Seat width should ideally accommodate the 95th%ile (520mm); however the "Jazz" chair's seat width only accommodated the 68th%ile of the male sample.

Backrest height for the male sample should adjust to accommodate the 5th%ile to 95th%ile (430mm to 570mm) and backrest width should accommodate the 50th%ile (440mm). The backrest minimum height (470mm) of the "Jazz" chair was too high however: the backrest width accommodated the 38th%ile male sample.

The male sample armrest height should adjust between the 5th%ile to 95th%ile (140mm to 240mm) and the armrest length should accommodate the 50th%ile (260mm). The minimum height of the “Jazz” office chair armrest was too high for the male sample and the armrest length was too long.

Lumbar support height should ideally accommodate the 5th%ile to 95th%ile (140mm to 220mm) and the edge of the lumbar support should also accommodate the 5th%ile to 95th%ile (110mm to 190mm) for the male sample. The edge of the lumbar support of the “Jazz” office chair did not accommodate the male sample.

The backrest point and lumbar support point should accommodate the 50th%ile (580mm and 520mm respectively). The cushion, which is the space between the lumbar support and backrest support, would be 60mm in depth; however the cushion depth only accommodated the 13^{th}%ile male sample.

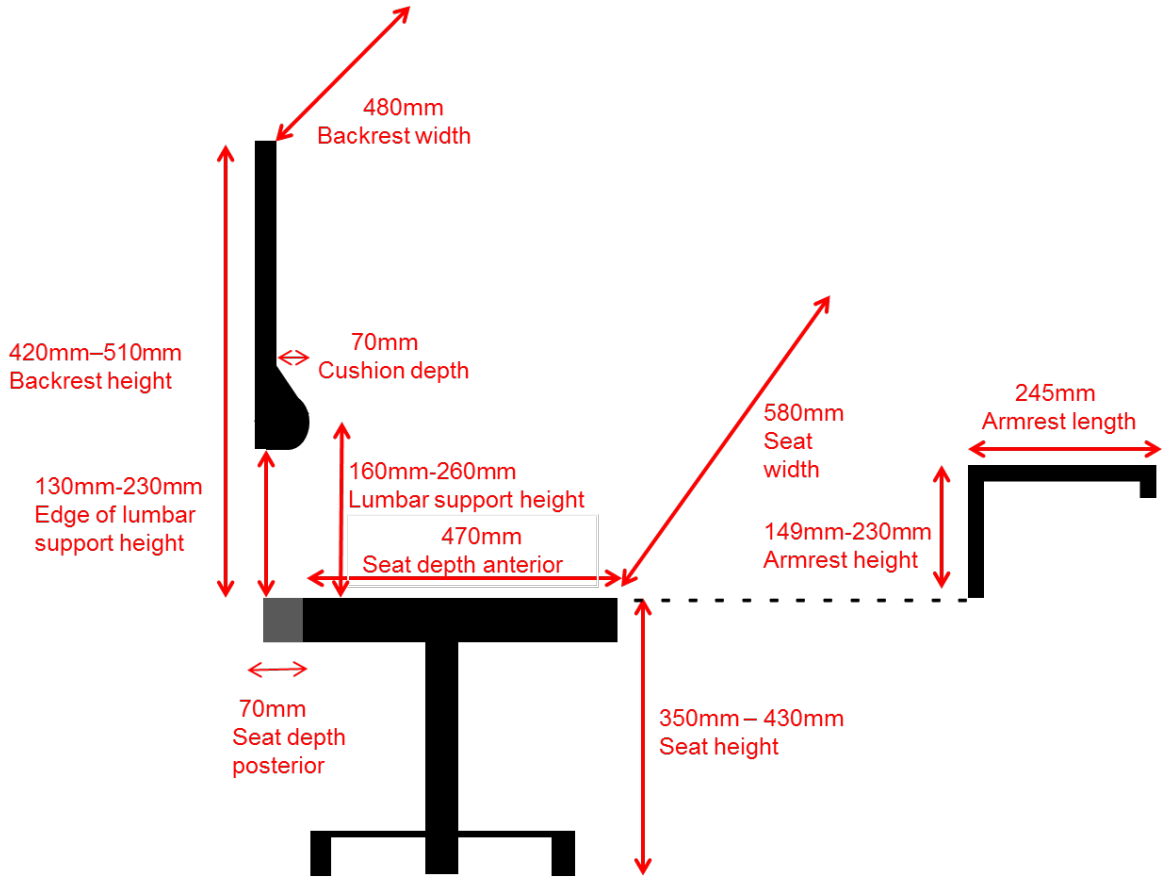

Figure 44: Anthropometric office chair dimensions of the Black female sample.

(Refer to Table XXIX, in Results section, page 85)

A specific chair for the Black female population should comprise a seat height adjustable from 350mm to 430mm; a seat depth anterior of 470mm and a seat depth posterior of 70mm. The "Jazz" office chair minimum seat height was too high for the Black female sample, while the seat depth anterior and posterior were too short. When considering specific female groupings within the general South African population, the outlook is worse: current seat width (480mm) accommodates the 58th %ile of Black females with a 100mm deficit to reach the ideal seat width

The Black female sample backrest height should be adjustable between 420mm and 510mm and the backrest width should be 480mm. The minimum backrest height was too high and the backrest width (440mm) was too narrow for the Black female sample.

The armrest height should be adjustable between 149mm and 230mm and the armrest length would be 245mm. The armrest minimum height and the armrest length were too high and too long for the Black female sample.

The lumbar support height and edge of lumbar support should range between the 5th%ile to the 95th%ile (160mm to 260mm and 130mm to 230mm respectively). The lumbar support maximum height accommodated the 68th%ile of the Black females and the edge of the lumbar support did not accommodate the Black female sample.

The backrest point and lumbar support point should be 580mm and 510mm respectively. The cushion, which is the space between the lumbar support point and backrest point, would be 70mm. However; the cushion depth only accommodated the 13th%ile of the Black female sample instead of the 50th%ile.

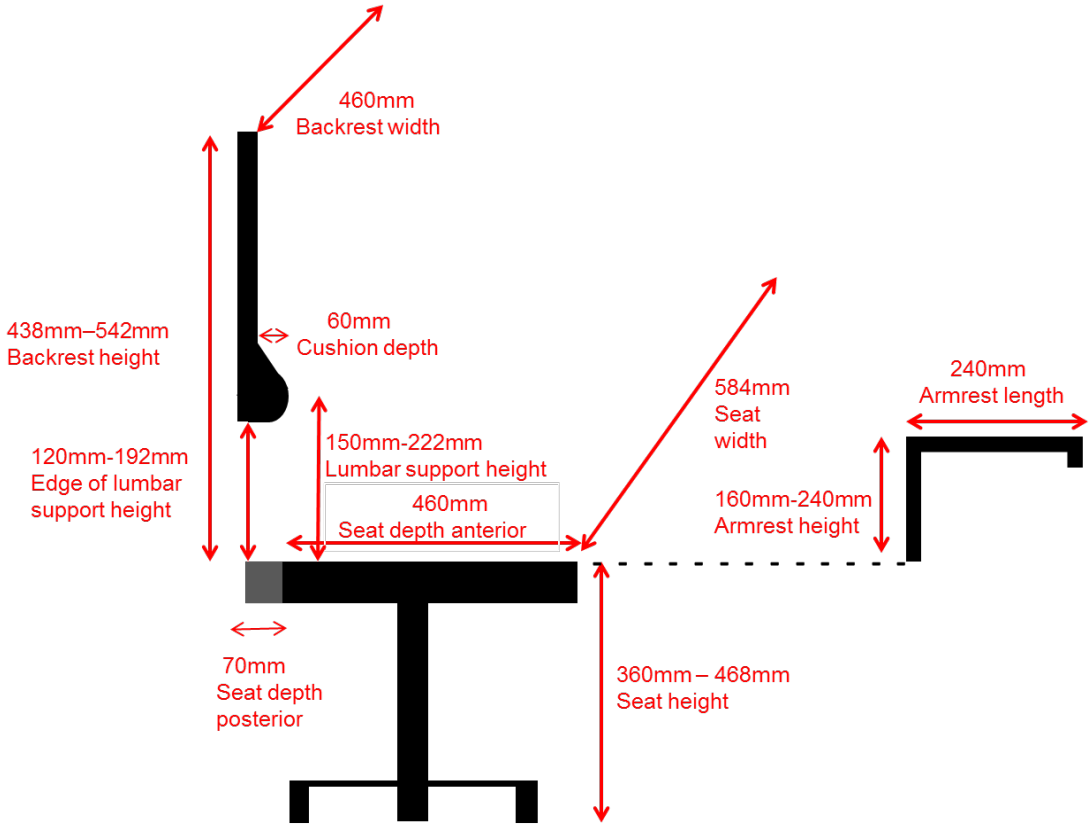

Figure 45: Anthropometric office chair dimensions of the White female sample**.**
(Refer to Table XXX, in Results section, page 85)

The White female sample would need a seat height adjustable between 360mm and 468mm; a seat depth anterior should be 460mm and seat depth posterior should be 70mm. The “Jazz” office chair did not accommodate the White female seat height, seat depth anterior or seat depth posterior dimensions. The seat width should be 584mm: the “Jazz” office chair accommodated the 72nd%ile of the White female sample; however this should be the 95th%ile.

The backrest height should ideally be able between 438mm and 542mm and the backrest width should be 460mm. The minimum backrest height for the “Jazz” office chair was 470mm and this was too high for the White female sample. The backrest width was also too narrow for the White female sample.

The armrest height should be adjustable between 160mm and 240mm and the armrest length should be 240mm. The armrest minimum height and the armrest length were also too great for the White female sample.

The lumbar support height and edge of lumbar support should ideally range between the 5th%ile to the 95th%ile (150mm to 222mm and 120mm to 192mm respectively). However; maximum height of the edge of the lumbar support height of the “Jazz” office chair was only 80mm. This was too short to support the buttocks area of the White female sample.

The backrest point and lumbar support point should be 570mm and 510mm respectively and the cushion depth, which is the space between the lumbar support point and backrest point, should be 60mm for the White female sample. Only the 18th%ile of the White female sample was accommodated by the “Jazz” office chair’s cushion depth.

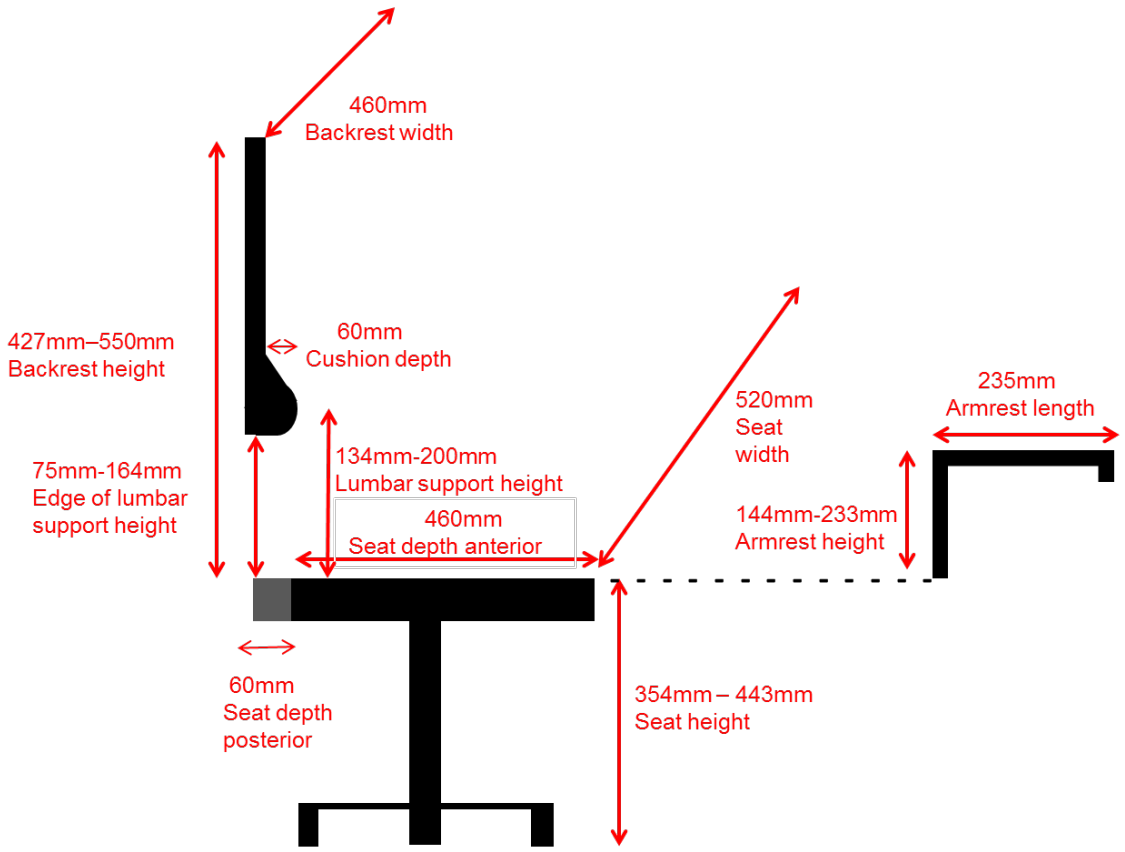

Figure 46: Anthropometric office chair dimensions of the Coloured female sample.

(Refer to Table XXXI, in Results section, page 85)

The Coloured female sample office chair should ideally have a seat pan that has a seat height adjustable from 354mm to 443mm; a seat depth anterior of 460mm; seat depth posterior of 60mm and a seat width of 520mm. The “Jazz” office chair seat height adjusted between 440mm and 560mm, indicating that the minimum height was too high; the seat depth anterior was too short (430mm) and the seat depth posterior (20mm) was also too short to support the Coloured female sample.

Backrest height should be adjustable between 427mm and 550mm and the backrest width would be 460mm. The minimum backrest height of the “Jazz” office chair was too high for the Coloured females; however the backrest width accommodated the Coloured female sample (44th%ile).

Armrest height should ideally be adjustable between 144mm and 233mm and the armrest length should be 235mm. The “Jazz” office chair had an armrest height of

240mm and this was too high for the Coloured female sample. The armrest length (260mm) was also too long.

The lumbar support height and edge of lumbar support should range between the 5th%ile to the 95th%ile (134mm to 200mm and 104mm to 170mm respectively). The minimum lumbar support height (120mm) was too short for the Coloured females and the edge of the lumbar support also did not accommodate the Coloured female sample.

The backrest point and lumbar support point would be 540mm and 490mm respectively. The cushion, which is the space between the lumbar support point and backrest point, would be 60mm. The "Jazz" office chair accommodated only the 19th%ile of the Coloured female sample indicating that a greater cushion depth would be needed.

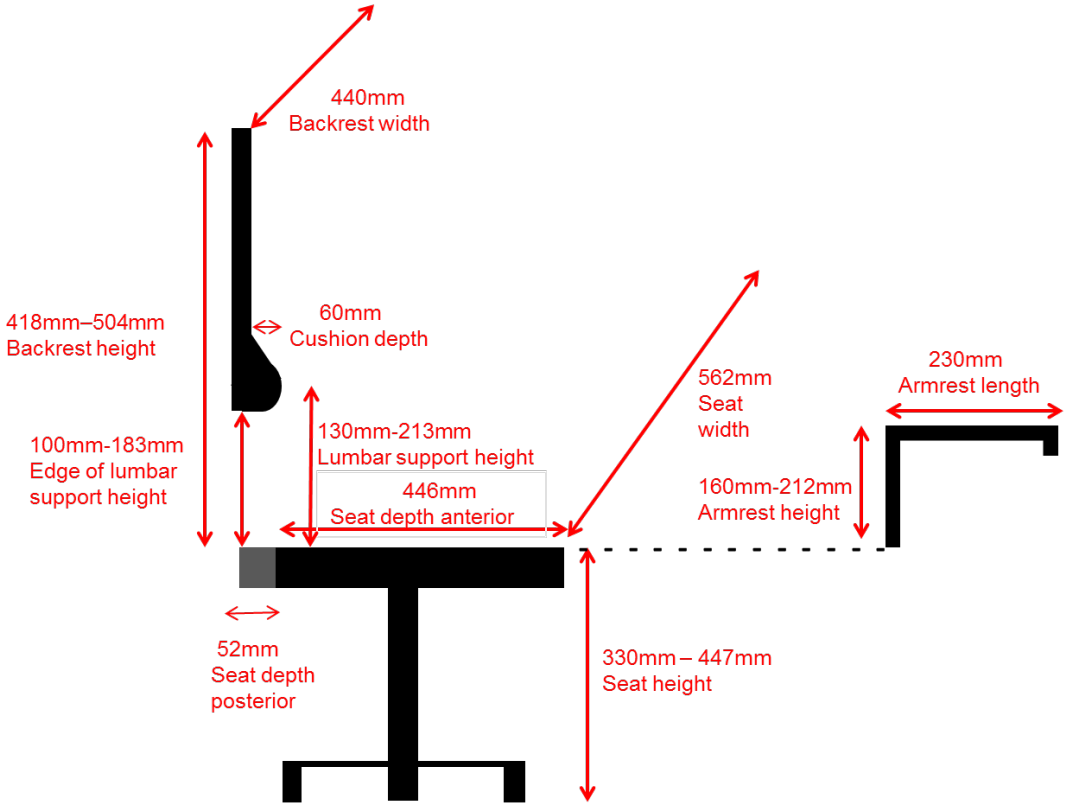

Figure 47: Anthropometric office chair dimensions of the Indian/Asian female sample.

(Refer to Table XXXII, in Results section, page 85)

A specific chair for the Indian/Asian female sample should ideally comprise of a seat height adjusting from 330mm to 447mm; a seat depth anterior of 446mm; a seat depth posterior of 52mm and a seat width of 562mm. The seat height of the "Jazz" office chair was too high for the sample as the minimum height was 440mm; the seat depth anterior accommodated the Indian/Asian females, but the seat depth posterior was not sufficient to support the buttocks. The seat width accommodated the 83rd%ile, most of the Indian/Asian female sample.

The "Jazz" office chair backrest height ranged between 470mm and 550mm and the Indian/Asian female backrest height should be adjustable between 418mm and 504mm. This indicated that the minimum backrest height was too great for the Indian/Asian female sample. The backrest width should be 440mm and the "Jazz" office chair had the exact backrest width of 440mm.

Armrest height should ideally adjust between 160mm and 212mm and the armrest length should be 230mm. The "Jazz" office chair had an armrest height of 240mm and armrest length of 260mm.

The "Jazz" office chair lumbar support and edge of lumbar support ranged between 120mm and 220mm; 0mm and 80mm. The lumbar support height and edge of lumbar support for the Indian/Asian female sample should range between the 5th%ile to the 95th%ile (130mm to 213mm and 100mm to 183mm respectively). The main concern was the edge of the lumbar support, as it did not allow adequate space for the buttocks.

The backrest point and lumbar support point should be 550mm and 490mm respectively. The cushion, which is the space between the lumbar support point and backrest point, should be 60mm; however the "Jazz" office chair cushion depth only supported the 12%ile of Indian/Asian females.

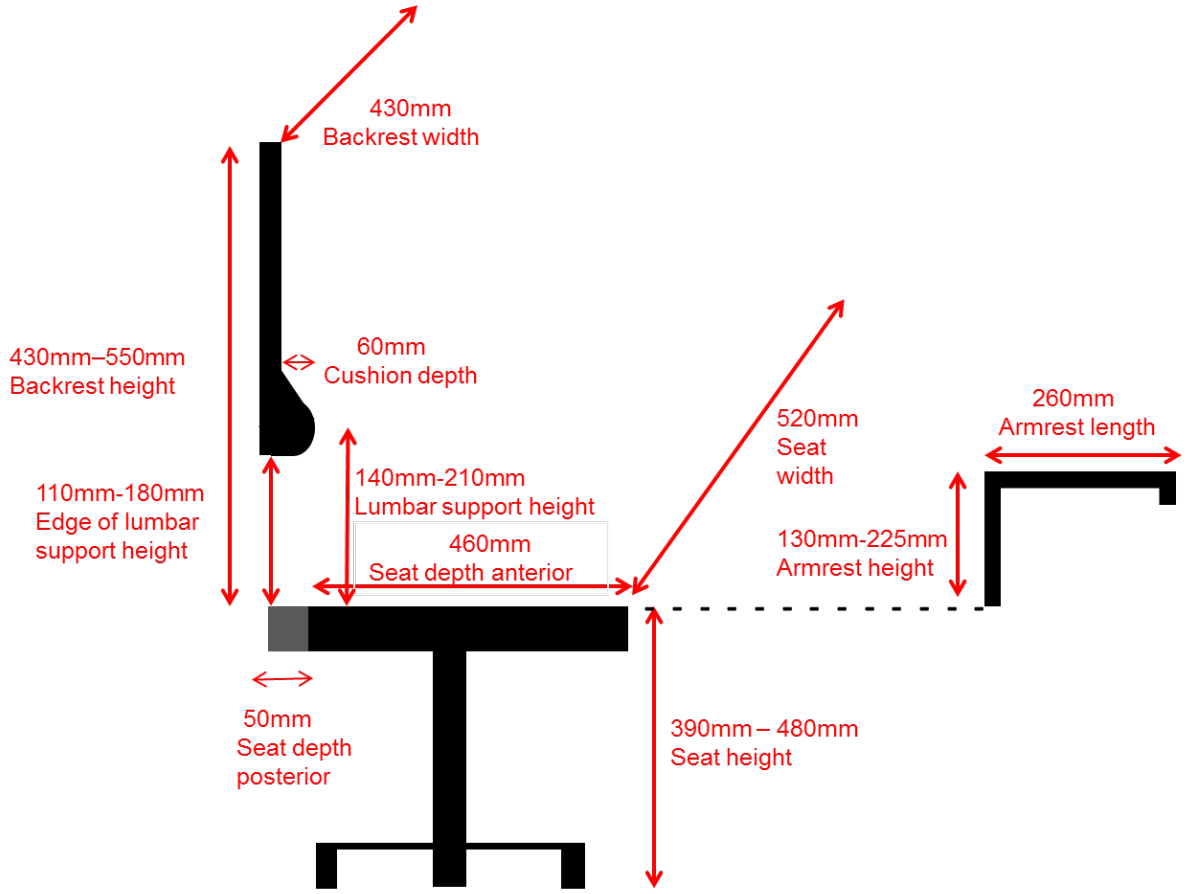

Figure 48: Anthropometric office chair dimensions of the Black male sample.

(Refer to Table XXXIII, in Results section, page 85)

Seat height should be adjustable between 390mm and 480mm; a seat depth anterior would need to be 460mm; seat depth posterior would need to be 50mm and the seat width would be 520mm for the Black male sample. The seat height of the "Jazz" office chair (440mm to 560mm) did not accommodate the lower percentiles as 440mm was the 68th%ile for the Black males. The seat depth anterior and posterior was too short for the Black male sample; however the seat width of the "Jazz" office chair (480mm) accommodated 87% of the Black male sample.

Backrest height should range between 430mm and 550mm; the backrest width should be 430mm. The minimum backrest height of the "Jazz" office chair was 470mm and this accommodated the 51st%ile instead of the 5th%ile; therefore the backrest height was too high for the Black male sample. However, the backrest width was suitable for the Black male sample.

The armrest height was 240mm and the armrest length was 260mm for the “Jazz” office chair. The Black male sample should ideally have an armrest height that would adjust between 130mm and 225mm, and the armrest length should be 260mm. The armrest height was too high for the Black male sample; however the armrest length was perfect for the Black male sample.

The lumbar support height and edge of lumbar support would also range between the 5th%ile to the 95th%ile (140mm to 210mm and 110mm to 180mm respectively). The lumbar support of the “Jazz” office chair accommodated the Black male sample, however the edge of the lumbar support did not.

The backrest point and lumbar support point should be 590mm and 520mm respectively and the cushion, which is the space between the lumbar support point and backrest point, should be 60mm. The cushion depth (40mm) of the “Jazz” office chair was not adequate for the Black male sample.

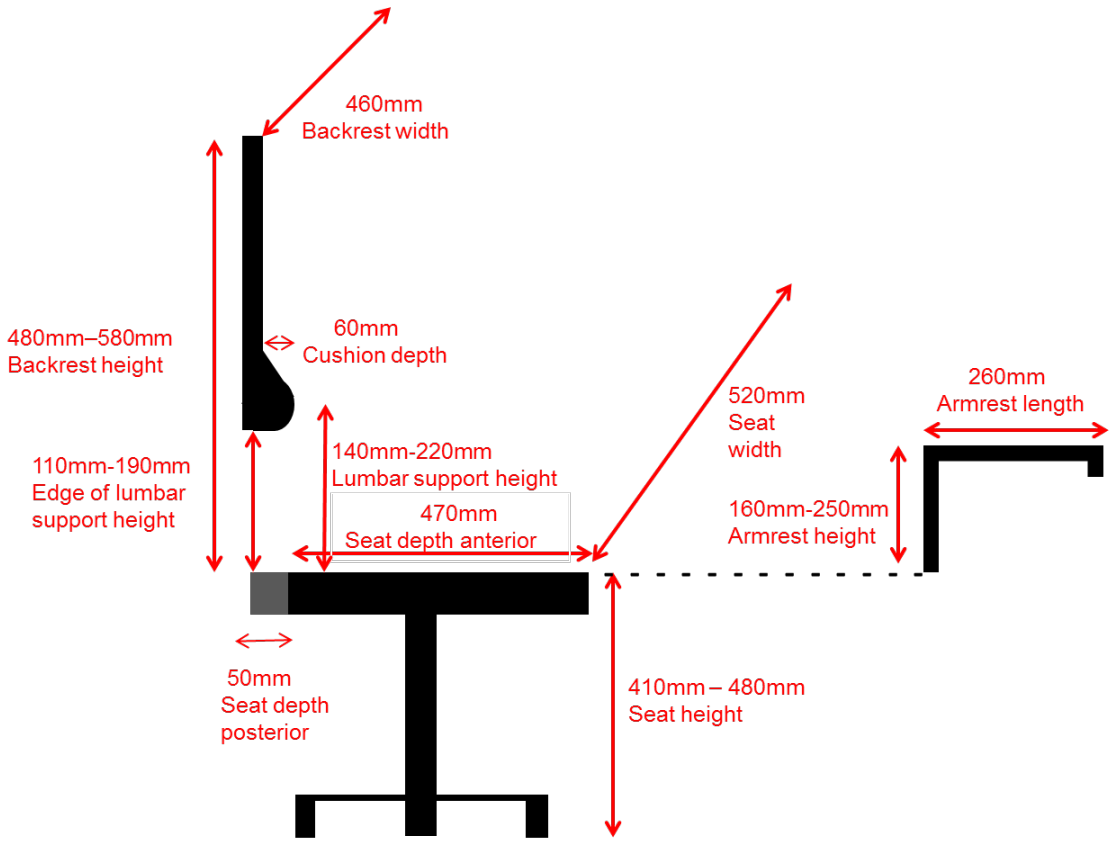

Figure 49: Anthropometric office chair dimensions of the White male sample.

(Refer to Table XXXIV, in Results section, page 85)

A specific chair for the White male sample would comprise of a seat height adjustable from 410mm to 480mm; a seat depth anterior of 470mm; seat depth posterior of 50mm and a seat width of 520mm. Although the White male sample had the greatest seat height of all groups, the minimum seat height of the "Jazz" office chair was too high (440mm). The "Jazz" seat depth anterior and seat depth posterior were too short and the seat width was too narrow for the White male sample.

The backrest height would need to be adjustable between 480mm and 580mm, and the backrest width should be 460mm for the White male sample. The backrest height ranged between 470mm to 550mm and backrest width was 440mm for the "Jazz" office chair. The White male sample would need a slightly higher backrest and a greater backrest width.

The armrest length (260mm) of the “Jazz” office chair accommodated the White male sample; however the armrest height would need to be adjustable between 160mm and 250mm and the “Jazz” office chair only accommodated the 93rd%ile. A shorter armrest would also be needed for the White male sample.

The lumbar support height and edge of lumbar support would also range between the 5th%ile to the 95th%ile (140mm to 220mm and 110mm to 190mcm respectively). The lumbar support height of the “Jazz” office chair accommodated the White male sample; however, the edge of the lumbar support did not allow for adequate buttocks space.

The backrest point and lumbar support point should be 590mm and 530mm respectively and the cushion depth, which is the space between the lumbar support point and backrest point, should be 60mm, however, a greater cushion depth would be needed for the “Jazz” office chair, to support the back and lumbar curve of the White male sample.

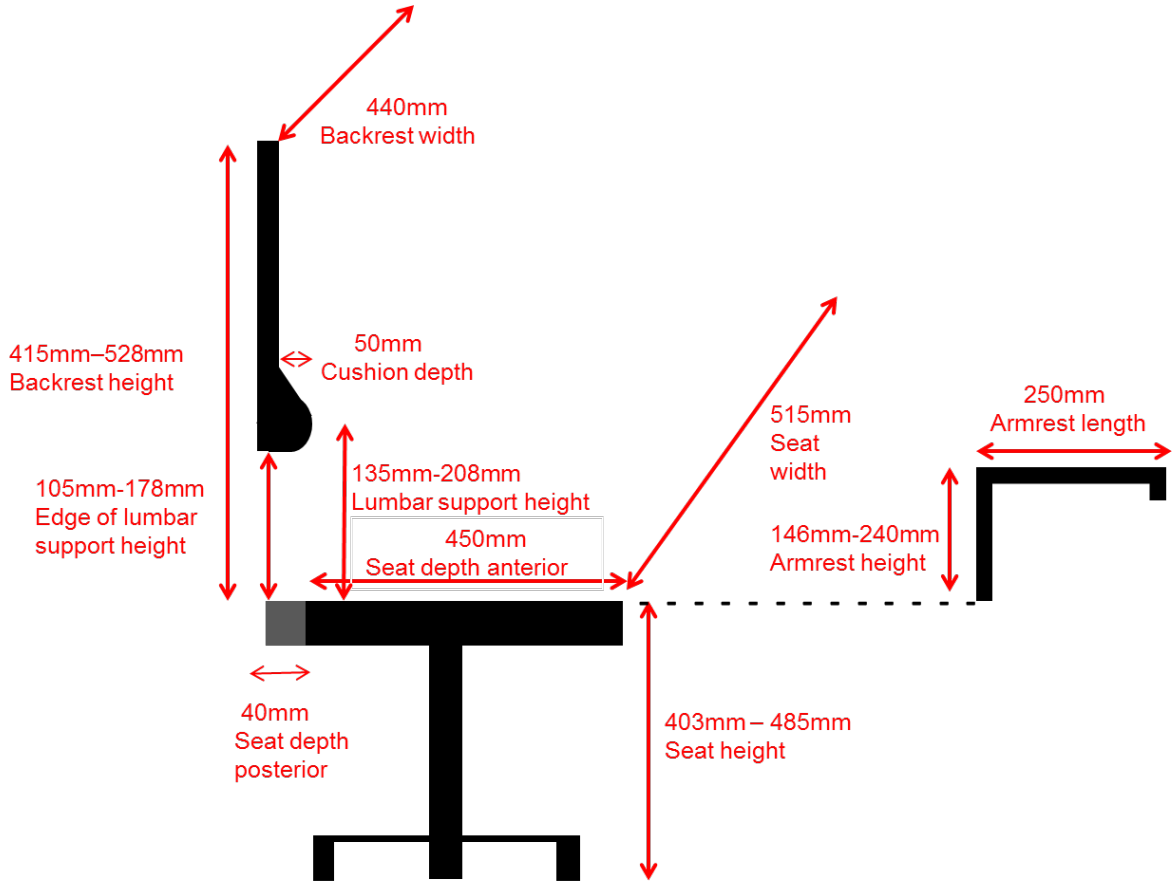

Figure 50: Anthropometric office chair dimensions of the Coloured male sample.

(Refer to Table XXXV, in Results section, page 85)

The Coloured seat pan would need to have a seat height that would be adjustable from 403mm to 485mm; a seat depth anterior of 450mm; seat depth posterior of 40mm and a seat width of 515mm. The seat height of the "Jazz" office chair was 440mm to 560mm and the minimum seat height accommodated the 76th%ile of the Coloured male sample instead of the 5th%ile, indicating that the seat height was too high for the sample. The seat width accommodated the Coloured male sample (88th%ile).

The minimum backrest height (470mm) of the "Jazz" office chair was too high for the Coloured male sample's minimum backrest height, which should ideally be adjustable between 15mm and 528mm. The "Jazz" office chair backrest width did accommodate the Coloured male sample.

The armrest height of the “Jazz” office chair was too high for the Coloured male sample as the armrest height should be adjustable between 146mm and 240mm and the armrest for the “Jazz” office chair was 240mm in height. The armrest length (260mm) of the “Jazz” office chair was also too long for the Coloured male sample armrest length (250mm).

The lumbar support height and edge of lumbar support for the Coloured male sample should range between the 5th%ile to the 95th%ile (135mm to 208mm and 105mm to 178mm respectively). The 5^{th}%ile and 95^{th}%ile lumbar support height of the “Jazz” office chair did not accommodate the Coloured male sample, and neither did the dimensions for the edge of the lumbar support height.

The backrest point and lumbar support point would be 560mm and 510mm respectively. The cushion, which is the space between the lumbar support point and backrest point, would be 50mm. A larger cushion would be needed to support the back and lumbar curve of the Coloured male sample.

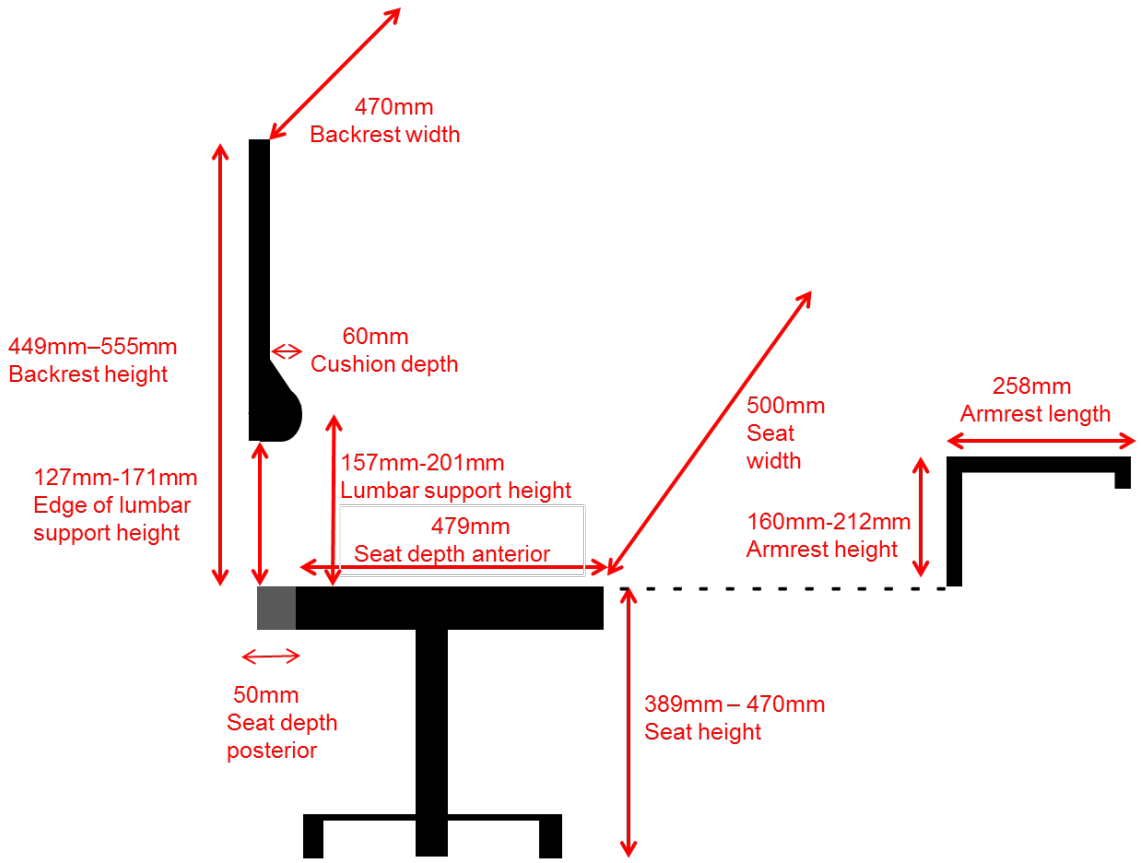

Figure 51: Anthropometric office chair dimensions of the Indian/Asian male sample.

(Refer to Table XXXVI, in Results section, page 85)

A specific chair for the Indian/Asian male sample would comprise of a seat height adjusting from 389mm to 470mm; a seat depth anterior of 479mm; a seat depth posterior of 50mm and a seat width of 500mm. The "Jazz" office chair had a seat height range between 440mm and 560mm. This indicates that only from the 64th%ile was the sample accommodated, instead of the 5th%ile. The seat height, seat depth anterior and seat depth posterior of the "Jazz" office chair did not accommodate the Indian/Asian male sample chair dimensions. However, the seat width accommodated the Indian/Asian males (82nd%ile).

The backrest height of the "Jazz" office chair adjusted from 470mm to 550mm and the Indian/Asian male sample would need a seat height to be adjustable between 449mm and 555mm. The minimum backrest height was too high for the Indian/Asian

sample as it accommodated the 29th%ile instead of the 5th%ile. The backrest width of the “Jazz” office chair accommodated the Indian/Asian male sample (41st%ile).

The armrest height should ideally adjust between 160mm and 212mm and the armrest length would be 258mm. The armrest height (240mm) of the “Jazz” office chair did not accommodate the Indian/Asian male sample as it was set too high; however, the armrest length (260mm) of the “Jazz” office chair accommodated the sample.

The lumbar support height and edge of lumbar support should range between the 5th%ile to the 95th%ile (157mm to 201mm and 127mm to 171mm respectively). The minimum lumbar support height (120mm) did not accommodate the Indian/Asian males, however the maximum lumbar support did (210mm). The edge of the lumbar support height (0mm to 80mm) of the “Jazz” office chair did not accommodate the Indian/Asian male sample.

The backrest point and lumbar support point would be 580mm and 510mm respectively. The space between the lumbar support point and backrest point, the cushion depth, should be 60mm. The cushion of the “Jazz” office chair would also need to increase in depth to support the Indian/Asian males.

CHAPTER VI

SUMMARY, CONCLUSION AND RECOMMENDATIONS

INTRODUCTION

Discomfort due to seated work is a result of incorrect posture while working for long durations. Office chairs should be manufactured specifically for populations and not just to the dimensions of European and USA countries. Designing for specific populations and ethnic groups and correctly adjusting an office chair to suit a specific individual will reduce the discomfort of office chairs and provide adequate support while seated. Office chair design should be an on-going process and should be constantly changing to accommodate the changes in anthropometric dimensions of the population. The South African population has specific anthropometric dimensions, especially for the Black female population.

SUMMARY OF PROCEDURES

The current research examined the anthropometric measurements and office chair measurements of the South African population (sex and ethnic groups) to determine guidelines for office chair design. A total of 683 participants around South Africa participated in the research around South African.

Specific office chair measurements were selected. The measurements consisted of personal information such as age (yrs); sex; ethnic group, home language, stature (mm); shoulder height (mm); mass (kg); body mass index (BMI) ($kg.m^{-2}$); waist circumference (mm); hip circumference (mm) and waist to hip ratio (WHR). Anthropometric measurements such as seat height (mm); seat depth anterior (mm) and posterior (mm); seat width (mm); backrest height (mm) and width (mm); armrest height (mm), armrest length (mm) and armrest width (mm); lumbar support height (mm) and edge of lumbar support (mm); thigh height (mm) were also taken. Each measuring session lasted about 5 minutes per participant.

Once the anthropometric data was recorded, the specific office chair dimensions were verified. An office chair was then constructed and modified according to the anthropometric office chair measurements that had been obtained for the South African sample. A current office chair's dimensions were also compared to the dimensions obtained from the South African sample and the specific dimensions relating to each group.

SUMMARY OF RESULTS

PARTICIPANT DIMENSIONS DEPENDENT ON 'SEX' AND 'ETHNIC GROUPS'

The White ethnic groups had a greater stature and shoulder height compared to the other ethnic groups and a similar trend was observed for a study done on Germans, Americans, British and south-eastern Nigerians (Onuoha *et al.,* 2012). Body mass and body mass index of the South African sample was a source of concern because the average male and female sample falls within the category classified as overweight. Obesity, diabetes and associated concerns affect more than half of the South African population (Puoane *et al.*, 2002). The current sample fell within these parameters with mean BMI (28.9±7.1kg.m^{-2}) indicating overweightness and borderline obesity, and WHR (0.9±7.1) reflective of cardiovascular diseases.

OFFICE CHAIR DIMENSIONS DEPENDENT ON 'SEX' AND 'ETHNIC GROUPS'

Unique dimensions inhered for each ethnic group as South African anthropometry is diverse. Many differences were observed within the South African sample. The Indian/Asian anthropometric dimension had greater variance with each anthropometric chair dimension whereas the Black sample had a relatively smaller variance for each office chair structure. The male sample had a greater seat height, seat depth anterior, backrest height and armrest length whereas the female sample had a greater seat depth posterior, seat width, backrest width, armrest height, lumbar support height, edge of lumbar support height cushion depth and thigh height.

CURRENT OFFICE CHAIR DIMENSIONS AND THE SOUTH AFRICAN OFFICE CHAIR DIMENSIONS

The “Jazz” medium back office chair’s (original office chair) dimensions were compared to the anthropometric chair dimensions obtained from the South African sample. It clearly shows in Table XXIII, in the results section, that the dimensions of the “Jazz” chair do not fully accommodate the dimensions of the total South African sample, nor the dimensions for each ethnic group. The seat width, seat length, lumbar support height and edge of lumbar support height are the main structures that would be problematic for the South African sample as these dimensions on the “Jazz” chair are unable to accommodate the unique South African anthropometry.

Without the correct seating and support of an office chair, discomfort and even injuries (Robertson et al., 2009) can result. Office chairs need to incorporate the unique anthropometric chair dimensions in office chair design to reduce discomfort and the rate of absenteeism in the workplace (Tulder *et al.,* 1995).

RESPONSE TO HYPOTHESES

1. *H_A: (Variables) Current chairs ≠ (Variables) South African dimensions*

The alternative hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, cushion depth, lumbar support minimum height, edge of lumbar support height) were not suitable for the South African sample.

2. *H_A: (Variables) Current chairs ≠ (Variables) South African Female sample*

The alternate hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, backrest width, cushion

depth, lumbar support height and edge of lumbar support height) were not suitable for the South African female sample.

H_A: (Variables) Current chairs ≠ (Variables) South African Male sample

The alternate hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, cushion depth, lumbar support minimum height and edge of lumbar support height) were not suitable for the South African male sample.

3. *H_A: (Variables) Current chairs ≠ (Variables) South African Black Female sample*

The alternate hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, backrest width, cushion depth, lumbar support height and edge of lumbar support height) were not suitable for the South African Black female sample.

H_A: (Variables) Current chairs ≠ (Variables) South African White Female sample

The alternate hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, backrest width, cushion depth, lumbar support minimum height and edge of lumbar support height) were not suitable for the South African White female sample.

H_A: (Variables) Current chairs ≠ (Variables) South African Coloured Female sample

The alternate hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, cushion depth, lumbar

support minimum height and edge of lumbar support height) were not suitable for the South African Coloured female sample.

H_A: (Variables) Current chairs ≠ (Variables) South African Indian/Asian Females

The alternate hypothesis was accepted as the current office chair dimensions (seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, cushion depth, lumbar support minimum height and edge of lumbar support height) were not suitable for the South African Indian/Asian female sample.

H_A: (Variables) Current chairs ≠ (Variables) South African Black Males

The alternate hypothesis was accepted as the current office chair dimensions (depth anterior, seat depth posterior, seat minimum height, armrest minimum height, backrest minimum height, cushion depth, lumbar support minimum height and edge of lumbar support height) were not suitable for the South African Black male sample.

H_A: (Variables) Current chairs ≠ (Variables) South African White Males

The alternate hypothesis was accepted as the current office chair dimensions (seat width, seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, backrest maximum height, backrest width, cushion depth, lumbar support minimum height and edge of lumbar support height) were not suitable for the South African White male sample.

H_A: (Variables) Current chairs ≠ (Variables) South African Coloured Males

The alternate hypothesis was accepted as the current office chair dimensions (seat depth anterior, seat depth posterior, seat minimum height, armrest minimum height, armrest length, backrest minimum height, backrest width, cushion depth, lumbar

support minimum height and edge of lumbar support height) were not suitable for the South African Coloured male sample.

H_A: (Variables) Current chairs ≠ (Variables) South African Indian/Asian Males

The alternate hypothesis was accepted as the current office chair dimensions (depth anterior, seat depth posterior, seat minimum height, armrest minimum height, backrest minimum height, cushion depth, lumbar support minimum height and edge of lumbar support height) were not suitable for the South African Indian/Asian male sample.

RELIABILITY OF THE DATA

The methods and techniques of measuring the anthropometric dimensions were adopted from previous studies that focused on the anthropometric dimensions of individuals. With any measuring method, human error will result in reduced reliability of data. Mochimaru and Kouchi (2011) performed a study on the magnitude of errors that are made when measuring landmarks on individuals for scientific research and the accuracy of the 3D body scan. The 3D body scan is more accurate as it eliminates the human error.

There are certain aspects within the methodology of collecting anthropometric data that could be changed or improved. Stature could have been measured more accurately using a Stadiometer instead of the standard dressmakers tape measure fastened on the wall. Skinfolds and Bioelectrical Impedance Analysis (BIA) could have been used to measure body composition however; this would have resulted in a longer testing duration. More accurate measurements of the seat pan and backrest would have been evident if a 3D scan of the seat pan was taken however the testing duration had to be kept to a minimum so that the testing would not interrupt the individuals work time. Repetitive measurements of the anthropometric landmarks could have been performed to improve the accuracy of the results however; this would have a huge impact on the data collection time. Inter-observation testing was

reduced as the researcher was the only individual measuring the anthropometric dimensions (Mochimaru and Kouchi, 2011).

Improved measuring techniques could have been used in the study to ensure more accurate and reliable results. However, the techniques of measuring and the measuring instruments were selected due to data collection time constraints with setting up of the equipment and the limited travel space.

CONCLUSION

The current study reveals the anthropometric dimensions of the South African population as well as the dimensions for each ethnic group (Black, White, Coloured and Indian/Asian). The data obtained in this study could be used as a guideline for chair manufacturers. The data revealed that the male sample has larger body dimensions than the female sample, except for hip circumference and body mass index. The male sample also requires larger chair dimensions than the female sample, except for seat depth posterior, seat width, backrest width, armrest height, lumbar support height, edge of lumbar support height, cushion depth and thigh height.

When referring to the dimensions of the South African sample and the different ethnic groups, it is evident that current South African chairs need to incorporate these anthropometric dimensions in their designs to ensure comfortable office chairs for the ethnic groups within the South African population.

There are a number of different office chair designs; however literature states that the conventional, ergonomic office chair is still the most widely accepted chair for long-duration chair sitting (Rehan, 2010). The office chair would need to be adjusted to the anthropometry of the user to ensure the proper support of armrests, backrest and lumbar support rest, and to maintain adequate stability (Bridger, 2003). Office chairs need to be designed more ergonomically to suit the user's anthropometry and provide adequate support to maintain the correct sitting posture (Jung, 2005).

RECOMMENDATIONS FOR FUTURE STUDIES

Reflecting back on the study, there are a few adjustments and changes that could have been implemented, such as the measuring techniques and equipment used, which could result in more accurate readings. Most of the anthropometric measures were recorded using a standard tape measure. This measuring technique could have been substituted for more accurate measuring equipment such as a 3D body scanner. Data could have been collected in more areas in South Africa and this would have increased the sample size and validity of the study. A test-retesting of the anthropometric and chair measurements to ensure reliability and validity could have been implemented.

Future recommendations for future studies would include testing the comfort of a number of different office chairs for each ethnic group and assessing whether a single South African office chair design would be suitable in terms of comfort for the whole South African population. Aesthetics play a huge role in comfort and selecting items. Therefore, it would be interesting to assess whether different colours and patterns on office chairs would have an effect on the South African population. Due to the diverse findings of this study, it is recommended that anthropometric dimensions be collated for all population groups worldwide to capture data from all ethnic groups.

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APPENDIX A: PARTICIPANT INFORMATION

A1. Letter of information to participants

A2. Consent form

APPENDIX A1

INFORMATION SHEET

Department of Human Kinetics and Ergonomics
Rhodes University
Grahamstown
Masters Project 2011

Thank you for volunteering to participate in my research project titled: "SOUTH AFRICAN ANTHROPOMETRIC DIMENSIONS FOR THE DESIGN OF AN ERGONOMIC OFFICE CHAIR." The research project is separated into two sections. The first section consists of obtaining anthropometrical data necessary for the design of an office chair. The second part of the research project consist of ranking the chairs on comfort and testing the influence that colour and patterns have on the comfort and selection of office chairs.

By designing an office chair specifically for a population, will reduce the effects of lower back pain and musculoskeletal disorders that arise from incorrect seating. You will be required to be seated on the anthropometrical measuring chair whereby the researcher will be recording the anthropometrical measures such as seat height, seat width, front seat depth, back seat depth, armrest height, armrest length, and distance between the armrests, backrest support height, backrest support width and lumbar support positioning. The testing duration will not last longer than 5 minutes.

This is a voluntary procedure and at any time you wish to withdraw from testing or you feel distressed and can't continue, inform the researcher as there will be no consequences for relinquishing the testing.

The data that will be collected will be stored on the researcher's computer until the completion of the thesis. However only the average measures of all the subjects will be presented on a poster and in a thesis. Anonymity will be protected as each subject will be given codes. Photographs might be taken for illustrative purposes but

only after permission has been granted by you as the subject and anonymity will be protected by blocking out your face.

Thank you for your time and co-operation.

Janice Korte
0724764037
g07k1812@campus.ru.ac.za

APPENDIX A2

CONSENT FORM

I, _____, have been fully informed of the research project entitled: “SOUTH AFRICAN ANTHROPOMETRIC DIMENSIONS FOR THE DESIGN OF AN ERGONOMIC OFFICE CHAIR.”, and hereby give my consent to be a subject in the above named research.

I am fully aware of the procedures involved as well as the potential risks and benefits associated with my participation, as explained to me verbally and in writing. In agreeing to participate in this research I accept joint responsibility together with the Human Kinetics and Ergonomics Department, in that should an accident or injury occur as a direct result of the protocol being performed during the study, the Human Kinetics and Ergonomics Department will be liable for costs which may ensue and will reimburse the subject to the full amount, i.e. doctors’ consultation, medication, rehabilitation etc. The Department will however, waiver any legal recourse against the researcher or Rhodes University in the event the injury is self-inflicted, due to negligence of the subject, or is in any other way not related directly to the study itself.

I understand and that I may express any concerns about my participation in this study to the researcher and that I need to promptly report symptoms of distress. I am aware that I may withdraw my consent and may withdraw from participation in this research at any time without any consequences. I am further aware that my anonymity will be protected at all times, and agree that all the information collected may be used and published for statistical or scientific purpose.

I have read the information sheet accompanying this form and understand all procedures. Any questions that have occurred to me have been answered to my satisfaction.

PARTICIPANT (or legal representative)

_____	_____	_____
(Print name)	(Signed)	(Date)

PERSON ADMINISTERING INFORMED CONSENT:

_____	_____	_____
(Print name)	(Signed)	(Date)

WITNESS:

_____	_____	_____
(Print name)	(Signed)	(Date)

APPENDIX B: TEST COLLECTION SHEET

B1. Anthropometric data collection sheet

APPENDIX B1

Anthropometric Data Collection Sheet

Participant code: _____ Home Language: _____

Age: _____ Ethnic group: _____

Sex: _____

Measurements:

Seat height: _____

Seat depth anterior: _____

Seat depth posterior: _____

Seat width: _____

Backrest height: _____

Backrest width: _____

Armrest height: _____

Armrest length: _____

Lumbar support height: _____

Backrest point: _____

Lumbar support point: _____

Thigh height: _____

Stature: _____

Shoulder height: _____

Mass: _____

BMI: _____

Waist circumference: _____

Hip circumference: _____

WHR: _____

APPENDIX C: SUMMARY REPORT

C1. Anthropometric measures of the South African ethnic sample groups.

C2. Scheff significant test for chair dimensions for ‘sex’, ‘ethnic groups’ and the interaction of both.

C3. Post Hoc tests for chair dimensions for ‘sex’, ‘ethnic groups’ and interaction of both.

APPENDIX C1

Anthropometric measures of the South African ethnic sample groups

BLACK FEMALES	Age (yrs)	Stature mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	34.8	1615	1307	80.0	30.7	979	1149	1.0
SD	10.1	68	56	20.2	7.4	162	151	3.2
CV	29.0	4	4	25.3	24.2	17	13	310.9
95TH%ILE	54.0	1730	1400	116.0	44.4	1242	1402	1.0
50TH%ILE	32.0	1620	1310	77.0	30.0	990	1140	0.9
5TH%ILE	22.0	1500	1220	50.0	19.9	720	928	0.7
MAX	65.0	1800	1420	149.0	55.1	1500	1640	58.0
MIN	18.0	1450	1110	40.0	16.7	590	620	0.7

WHITE FEMALES	Age (yrs)	Stature (mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	42.1	1670	1368	75.1	27.0	899	1088	0.9
SD	11.4	73	51	19.2	7.4	162	163	0.2
CV	27.2	4	4	25.5	27.4	18	15	18.7
95TH%ILE	61.0	1786	1442	110.0	38.6	1166	1356	1.0
50TH%ILE	42.0	1660	1370	67.0	25.3	860	1040	0.8
5TH%ILE	23.0	1558	1280	54.0	19.7	698	916	0.7
MAX	63.0	1870	1490	143.0	56.6	1490	1720	1.8
MIN	20.0	1530	1240	47.0	15.6	670	640	0.7

COLOURED FEMALES	Age (yrs)	Stature (mm)	shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	37.3	1629	1334	72.6	27.7	878	1068	0.8
SD	10.5	67	58	19.7	7.4	145	132	0.1
CV	28.1	4	4	27.1	26.9	17	12	13.6
95TH%ILE	55.0	1740	1420	103.4	36.5	1099	1270	0.9
50TH%ILE	34.0	1630	1340	68.0	27.2	880	1050	0.8
5TH%ILE	25.7	1501	1247	49.9	18.2	658	898	0.7
MAX	58.0	1750	1440	135.0	54.1	1150	1490	1.4
MIN	24.0	1480	1180	42.0	16.4	610	870	0.7

INDIAN/ASIAN FEMALES	Age (yrs)	Stature (mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	34.0	1584	1301	69.2	27.4	867	1054	0.8
SD	7.1	65	67	20.6	7.2	170	145	0.1
CV	20.8	4	5	29.7	26.4	20	14	13.1
95TH%ILE	44.6	1703	1390	90.4	38.2	1070	1255	1.0
50TH%ILE	34.0	1590	1300	70.0	24.6	80	1040	0.8
5TH%ILE	24.0	1506	1215	44.0	19.1	647	868	0.7
MAX	50.0	1730	1480	130.0	47.2	1250	1480	1.2
MIN	24.0	1470	1170	44.0	17.9	620	850	0.7

BLACK MALES	Age (yrs)	stature (mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	39.5	1711	1396	79.2	27.1	931	1040	0.9
SD	11.3	72	61	18.8	6.4	152	128	0.1
CV	28.7	4	4	23.8	23.6	16	12	8.8
95TH%ILE	58.0	1825	1510	114.5	39.6	1184	1275	1.0
50TH%ILE	39.0	1710	1400	76.0	25.9	910	1030	0.9
5TH%ILE	23.0	1600	1300	55.6	18.9	708	880	0.8
MAX	61.0	1920	1580	140.0	49.8	1370	1510	1.3
MIN	19.0	1540	1280	51.0	17.8	660	720	0.7

WHITE MALES	Age (yrs)	Stature (mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	47.6	1805	1462	90.0	28.2	1013	1077	0.9
SD	10.8	75	60	15.9	5.8	153	97	0.1
CV	22.8	4	4	17.7	20.5	15	9	9.3
95TH%ILE	60.0	1951	1571	115.1	35.1	1181	1181	1.0
50TH%ILE	50.0	1810	1460	89.0	27.2	990	1070	0.9
5TH%ILE	25.9	1710	1390	66.9	21.4	849	970	0.8
MAX	65.0	2040	1640	160.0	59.5	1800	1700	1.5
MIN	18.0	1650	1370	62.0	19.7	780	930	0.8

COLOURED MALES	Age (yrs)	Stature (mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	35.0	1720	1410	78.9	26.7	915	1038	0.9
SD	10.1	87	60	16.7	5.8	140	106	0.1
CV	28.9	5	4	21.2	21.5	15	10	8.4
95TH%ILE	51.5	1850	1510	99.3	35.2	1083	1243	1.0
50TH%ILE	33.5	1705	1400	80.0	27.9	938	1040	0.9
5TH%ILE	20.5	1613	1340	56.5	19.2	708	903	0.8
MAX	61.0	1960	1580	124.0	40.5	1210	1280	1.0
MIN	20.0	1590	1330	55.0	18	660	900	0.7

INDIAN/ASIAN MALES	Age (yrs)	Stature (mm)	Shoulder height (mm)	Mass (kg)	BMI ($Kg.m^{-2}$)	Waist circumference (mm)	Hip circumference (mm)	WHR
MEAN	43.9	1731	1401	78.8	26.4	961	1034	0.9
SD	9.5	96	70	12.7	4.1	113	64	0.1
CV	21.6	6	5	16.1	15.4	12	6	8.4
95TH%ILE	54.4	1915	1535	96.7	31.4	1128	1130	1.0
50TH%ILE	45.0	1725	1415	78.5	27.3	930	1045	0.9
5TH%ILE	24.7	1604	1289	62.1	20.9	803	949	0.8
MAX	62.0	1940	1560	106.0	34.3	1170	1130	1.1
MIN	23.0	1570	1280	57.0	20.2	760	940	0.8

APPENDIX C2

Scheff significant test for chair dimensions for 'sex', 'ethnic groups' and the interaction of both. Shaded areas indicate significant differences ($p<0.05$).

2-Factorial analysis of Seat Height considering 'Ethnic groups' and 'Sex'.

	Degree of Freedom	F	p
Sex	**1,675**	**196.97**	**<0.01**
Ethnical group	**3,675**	**14.29**	**<0.01**
Sex*Ethnic group	3,675	1.2	0.31

2-Factorial analysis of Seat Depth Anterior considering 'Ethnic groups' and 'Sex'.

	Degree of Freedom	F	p
Sex	**1, 675**	**28.67**	**<0.01**
Ethnical group	**3, 675**	**4.39**	**<0.01**
Sex*Ethnic group	3, 675	2.07	0.11

2-Factorial analysis of Seat Depth Posterior considering 'Ethnic groups' and 'Sex'.

	Degree of Freedom	F	p
Sex	**1,675**	**54.674**	**<0.01**
Ethnical group	3, 675	2.044	0.11
Sex*Ethnic group	3, 675	0.794	0.5

2-Factorial analysis of Seat Width considering 'Ethnic groups' and 'Sex'.

	Degree of Freedom	F	p
Sex	**1,675**	**7.85**	**<0.01**
Ethnical group	**3,675**	**2.98**	**<0.03**
Sex*Ethnic group	**3,675**	**9.59**	**<0.01**

2-Factorial analysis of Backrest Height considering 'Ethnic groups' and 'Sex'.

	Degree of Freedom	F	p
Sex	**1,675**	**36.51**	**<0.01**
Ethnical group	**3,675**	**37.9**	**<0.01**
Sex*Ethnic group	**3,675**	**8.01**	**<0.01**

2-Factorial analysis of Backrest Width considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**7.85**	**<0.01**
Ethnical group	**3,675**	**2.98**	**<0.03**
Sex*Ethnic group	**3,675**	**9.59**	**<0.01**

2-Factorial analysis of Armrest Height considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	1,675	3.57	0.06
Ethnical group	**3,675**	**19.83**	**<0.01**
Sex*Ethnic group	**3,675**	**3.12**	**<0.03**

2-Factorial analysis of Armrest Length considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**91.54**	**<0.01**
Ethnical group	**3,675**	**6.7**	**<0.01**
Sex*Ethnic group	3,675	1.86	0.13

2-Factorial analysis of Lumbar Support Height considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**10.82**	**<0.01**
Ethnical group	**3,675**	**16.25**	**<0.01**
Sex*Ethnic group	**3,675**	**30.27**	**<0.01**

2-Factorial analysis of Edge of Lumbar Support Height considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**10.747**	**<0.01**
Ethnical Group	**3,675**	**16.153**	**<0.01**
Sex*Ethnic Group	**3,675**	**30.077**	**<0.01**

2-Factorial analysis of Thigh Height considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	1,675	0.329	0.57
Ethnical group	**3,675**	**7.848**	**<0.01**
Sex*Ethnic group	**3,675**	**3.358**	**<0.02**

2-Factorial analysis of Stature considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**227.5**	**<0.01**
Ethnical Group	**3,675**	**41**	**<0.01**
Sex*Ethnic Group	**3,675**	**4.8**	**<0.01**

2-Factorial analysis of Shoulder Height considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**196.8**	**<0.01**
Ethnical Group	**3,675**	**44.4**	**<0.01**
Sex*Ethnic Group	3,675	0.7	0.53

2-Factorial analysis of Mass considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**10.234**	**<0.01**
Ethnical group	**3,675**	**3.33**	**<0.02**
Sex*Ethnic group	**3,675**	**7.024**	**<0.01**

2-Factorial analysis of BMI considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	1,675	3.291	0.07
Ethnical group	3,675	2.233	0.08
Sex*Ethnic group	**3,675**	**4.774**	**0.01**

2-Factorial analysis of Waist Circumference considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**6.62**	**<0.01**
Ethnical group	**3,675**	**3.15**	**<0.02**
Sex*Ethnic group	**3,675**	**11.48**	**<0.01**

2-Factorial analysis of Hip Circumference considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1, 675**	**10.55**	**<0.01**
Ethnical group	**3, 675**	**2.69**	**<0.05**
Sex*Ethnic group	**3, 675**	**5.42**	**<0.01**

2-Factorial analysis of WHR considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1, 675**	**43.42**	**<0.01**
Ethnical group	**3, 675**	**2.75**	**<0.04**
Sex*Ethnic group	**3, 675**	**2.63**	**<0.05**

2-Factorial analysis of Backrest Point considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	1, 675	0.199	0.66
Ethnical group	**3, 675**	**3.159**	**<0.02**
Sex*Ethnic group	**3, 675**	**10.754**	**<0.01**

2-Factorial analysis of Lumbar Support Point considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	**1,675**	**27**	**<0.01**
Ethnical Group	**3,675**	**4.99**	**<0.01**
Sex*Ethnic Group	**3,675**	**1.86**	**0.13**

2-Factorial analysis of Cushion Depth considering ‘Ethnic groups’ and ‘Sex’.

	Degree of Freedom	F	p
Sex	1, 675	3.3	0.07
Ethnical group	3, 675	1.99	0.11
Sex*Ethnic group	**3, 675**	**7.609**	**<0.01**

APPENDIX C3

Post Hoc tests for chair dimensions for ‘sex’, ‘ethnic groups’ and interaction of both. Shaded areas indicate significant differences (p<0.05).

Scheffe Test; Variable Seat Height Probabilities for Post Hoc Tests

Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000002	0.925114	1.000000	0.000000	0.000000	0.000000	0.000000
Female	White	0.000002		0.486135	0.246216	0.000000	0.000000	0.006800	0.054831
Female	Coloured	0.925114	0.486135		0.997429	0.000000	0.000000	0.000017	0.000476
Female	Indian/Asian	1.000000	0.246216	0.997429		0.000000	0.000000	0.000017	0.000238
Male	Black	0.000000	0.000000	0.000000	0.000000		0.224189	1.000000	1.000000
Male	White	0.000000	0.000000	0.000000	0.000000	0.224189		0.841274	0.887407
Male	Coloured	0.000000	0.006800	0.000017	0.000017	1.000000	0.841274		1.000000
Male	Indian/Asian	0.000000	0.054831	0.000476	0.000238	1.000000	0.887407	1.000000	

Scheffe Test; Variable Seat Depth Anterior Probabilities for Post Hoc Tests

Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.906802	0.103933	0.137535	0.530306	0.381520	0.999903	0.999902
Female	White	0.906802		0.784806	0.654560	0.159469	0.102678	0.958929	0.973753
Female	Coloured	0.103933	0.784806		0.999820	0.004167	0.002468	0.344281	0.466724
Female	Indian/Asian	0.137535	0.654560	0.999820		0.012055	0.007155	0.266645	0.352740
Male	Black	0.530306	0.159469	0.004167	0.012055		0.999948	0.999275	0.999899
Male	White	0.381520	0.102678	0.002468	0.007155	0.999948		0.993716	0.998624
Male	Coloured	0.999903	0.958929	0.344281	0.266645	0.999275	0.993716		1.000000
Male	Indian/Asian	0.999902	0.973753	0.466724	0.352740	0.999899	0.998624	1.000000	

Scheffe Test; Variable Seat Depth Posterior Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.997434	0.656888	0.989345	0.000000	0.000000	0.000001	0.193030
Female	White	0.997434		0.961516	0.999828	0.000004	0.000007	0.000280	0.518947
Female	Coloured	0.656888	0.961516		0.999964	0.161323	0.122772	0.089941	0.979008
Female	Indian/Asian	0.989345	0.999828	0.999964		0.223277	0.173515	0.102298	0.940776
Male	Black	0.000000	0.000004	0.161323	0.223277		0.999990	0.974931	0.993385
Male	White	0.000000	0.000007	0.122772	0.173515	0.999990		0.994900	0.981691
Male	Coloured	0.000001	0.000280	0.089941	0.102298	0.974931	0.994900		0.867654
Male	Indian/Asian	0.193030	0.518947	0.979008	0.940776	0.993385	0.981691	0.867654	

Scheffe Test; Variable Seat Width Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.703579	0.137954	0.209723	0.000000	0.230895	0.013083	0.426672
Female	White	0.703579		0.930817	0.861631	0.001161	0.999519	0.454149	0.960440
Female	Coloured	0.137954	0.930817		0.999946	0.720357	0.993921	0.993012	1.000000
Female	Indian/Asian	0.209723	0.861631	0.999946		0.991481	0.965977	0.999981	0.999999
Male	Black	0.000000	0.001161	0.720357	0.991481		0.014004	0.999710	0.958540
Male	White	0.230895	0.999519	0.993921	0.965977	0.014004		0.720824	0.995148
Male	Coloured	0.013083	0.454149	0.993012	0.999981	0.999710	0.720824		0.999358
Male	Indian/Asian	0.426672	0.960440	1.000000	0.999999	0.958540	0.995148	0.999358	

Scheffe Test; Variable Backrest Height Probabilities for Post Hoc Tests

Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000156	0.728478	0.916907	0.027610	0.000000	0.965136	0.026532
Female	White	0.000156		0.937067	0.015457	0.897418	0.000000	0.863254	0.992025
Female	Coloured	0.728478	0.937067		0.422489	0.999997	0.000000	0.999994	0.757774
Female	Indian/Asian	0.916907	0.015457	0.422489		0.143427	0.000000	0.679937	0.019209
Male	Black	0.027610	0.897418	0.999997	0.143427		0.000000	0.999365	0.736402
Male	White	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.208912
Male	Coloured	0.965136	0.863254	0.999994	0.679937	0.999365	0.000000		0.656485
Male	Indian/Asian	0.026532	0.992025	0.757774	0.019209	0.736402	0.208912	0.656485	

Scheffe Test; Variable Backrest Width Probabilities for Post Hoc Tests

Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.703579	0.137954	0.209723	0.000000	0.230895	0.013083	0.426672
Female	White	0.703579		0.930817	0.861631	0.001161	0.999519	0.454149	0.960440
Female	Coloured	0.137954	0.930817		0.999946	0.720357	0.993921	0.993012	1.000000
Female	Indian/Asian	0.209723	0.861631	0.999946		0.991481	0.965977	0.999981	0.999999
Male	Black	0.000000	0.001161	0.720357	0.991481		0.014004	0.999710	0.958540
Male	White	0.230895	0.999519	0.993921	0.965977	0.014004		0.720824	0.995148
Male	Coloured	0.013083	0.454149	0.993012	0.999981	0.999710	0.720824		0.999358
Male	Indian/Asian	0.426672	0.960440	1.000000	0.999999	0.958540	0.995148	0.999358	

Scheffe Test; Variable Armrest height Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.101870	0.999648	0.999860	0.004452	0.015114	0.999992	0.912383
Female	White	0.101870		0.925857	0.652469	0.000002	0.999911	0.633150	0.178044
Female	Coloured	0.999648	0.925857		0.997523	0.178802	0.772396	0.999147	0.870987
Female	Indian/Asian	0.999860	0.652469	0.997523		0.949394	0.459451	1.000000	0.998806
Male	Black	0.004452	0.000002	0.178802	0.949394		0.000000	0.803342	0.999985
Male	White	0.015114	0.999911	0.772396	0.459451	0.000000		0.415078	0.087197
Male	Coloured	0.999992	0.633150	0.999147	1.000000	0.803342	0.415078		0.993318
Male	Indian/Asian	0.912383	0.178044	0.870987	0.998806	0.999985	0.087197	0.993318	

Scheffe Test; Variable Armrest Length Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.689003	0.603052	0.655720	0.000000	0.000000	0.960733	0.149400
Female	White	0.689003		0.999553	0.995198	0.000000	0.000000	0.518630	0.019609
Female	Coloured	0.603052	0.999553		0.999989	0.000000	0.000000	0.391209	0.015365
Female	Indian/Asian	0.655720	0.995198	0.999989		0.000002	0.000003	0.396860	0.023944
Male	Black	0.000000	0.000000	0.000000	0.000002		1.000000	0.108669	0.996439
Male	White	0.000000	0.000000	0.000000	0.000003	1.000000		0.100433	0.992679
Male	Coloured	0.960733	0.518630	0.391209	0.396860	0.108669	0.100433		0.905777
Male	Indian/Asian	0.149400	0.019609	0.015365	0.023944	0.996439	0.992679	0.905777	

Scheffe Test; Variable Lumbar Support Height Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000000	0.000000	0.000005	0.000000	0.000000	0.000000	0.000201
Female	White	0.000000		0.065549	0.716853	0.004261	1.000000	0.059162	0.946319
Female	Coloured	0.000000	0.065549		0.999468	0.999995	0.059109	0.999994	0.982229
Female	Indian/Asian	0.000005	0.716853	0.999468		0.999917	0.702911	0.995635	0.999963
Male	Black	0.000000	0.004261	0.999995	0.999917		0.003302	0.999239	0.988920
Male	White	0.000000	1.000000	0.059109	0.702911	0.003302		0.053987	0.941402
Male	Coloured	0.000000	0.059162	0.999994	0.995635	0.999239	0.053987		0.951504
Male	Indian/Asian	0.000201	0.946319	0.982229	0.999963	0.988920	0.941402	0.951504	

Scheffe Test; Variable Edge of Lumbar Support Height Probabilities for Post Hoc Tests									
Sex	Ethic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000000	0.000000	0.000005	0.000000	0.000000	0.000000	0.000219
Female	White	0.000000		0.066592	0.718772	0.004382	1.000000	0.060133	0.946824
Female	Coloured	0.000000	0.066592		0.999474	0.999995	0.060079	0.999994	0.982412
Female	Indian/Asian	0.000005	0.718772	0.999474		0.999918	0.704890	0.995683	0.999964
Male	Black	0.000000	0.004382	0.999995	0.999918		0.003400	0.999248	0.989037
Male	White	0.000000	1.000000	0.060079	0.704890	0.003400		0.054896	0.941948
Male	Coloured	0.000000	0.060133	0.999994	0.995683	0.999248	0.054896		0.951965
Male	Indian/Asian	0.000219	0.946824	0.982412	0.999964	0.989037	0.941948	0.951965	

Scheffe Test; Variable Stature Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000007	0.996524	0.560197	0.000000	0.000000	0.000000	0.000000
Female	White	0.000007		0.267946	0.000330	0.030531	0.000000	0.155679	0.039326
Female	Coloured	0.996524	0.267946		0.462415	0.000005	0.000000	0.000392	0.000080
Female	Indian	0.560197	0.000330	0.462415		0.000000	0.000000	0.000000	0.000000
Male	Black	0.000000	0.030531	0.000005	0.000000		0.000000	0.999371	0.902591
Male	White	0.000000	0.000000	0.000000	0.000000	0.000000		0.000484	0.110522
Male	Coloured	0.000000	0.155679	0.000392	0.000000	0.999371	0.000484		0.997764
Male	Indian	0.000000	0.039326	0.000080	0.000000	0.902591	0.110522	0.997764	

Scheffe Test; Variable Thigh Height Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000274	0.999961	0.183726	0.091395	0.061137	0.993470	0.249727
Female	White	0.000274		0.297498	1.000000	0.774637	0.965595	0.734814	1.000000
Female	Coloured	0.999961	0.297498		0.611397	0.937054	0.843546	0.999958	0.674892
Female	Indian/Asian	0.183726	1.000000	0.611397		0.949955	0.989697	0.865204	1.000000
Male	Black	0.091395	0.774637	0.937054	0.949955		0.999912	0.998692	0.968684
Male	White	0.061137	0.965595	0.843546	0.989697	0.999912		0.989348	0.994476
Male	Coloured	0.993470	0.734814	0.999958	0.865204	0.998692	0.989348		0.897537
Male	Indian/Asian	0.249727	1.000000	0.674892	1.000000	0.968684	0.994476	0.897537	

Scheffe Test; Variable Shoulder Height Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.000000	0.532643	0.999547	0.000000	0.000000	0.000000	0.000000
Female	White	0.000000		0.215088	0.001833	0.133258	0.000000	0.209887	0.401900
Female	Coloured	0.532643	0.215088		0.727674	0.000025	0.000000	0.000456	0.003750
Female	Indian/Asian	0.999547	0.001833	0.727674		0.000000	0.000000	0.000001	0.000017
Male	Black	0.000000	0.133258	0.000025	0.000000		0.000000	0.995760	0.998376
Male	White	0.000000	0.000000	0.000000	0.000000	0.000000		0.019298	0.083912
Male	Coloured	0.000000	0.209887	0.000456	0.000001	0.995760	0.019298		1.000000
Male	Indian/Asian	0.000000	0.401900	0.003750	0.000017	0.998376	0.083912	1.000000	

Scheffe Test; Variable Mass Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.710578	0.794446	0.427810	0.999023	0.020035	0.999951	0.999983
Female	White	0.710578		0.999991	0.964523	0.978408	0.001233	0.999123	0.999680
Female	Coloured	0.794446	0.999991		0.995774	0.965815	0.012060	0.995801	0.998041
Female	Indian/Asian	0.427810	0.964523	0.995774		0.689314	0.006227	0.881594	0.923860
Male	Black	0.999023	0.978408	0.965815	0.689314		0.020894	1.000000	1.000000
Male	White	0.020035	0.001233	0.012060	0.006227	0.020894		0.389641	0.590489
Male	Coloured	0.999951	0.999123	0.995801	0.881594	1.000000	0.389641		1.000000
Male	Indian/Asian	0.999983	0.999680	0.998041	0.923860	1.000000	0.590489	1.000000	

Scheffe Test; Variable BMI Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.012576	0.694619	0.750893	0.000595	0.278689	0.243844	0.300297
Female	White	0.012576		0.999176	1.000000	1.000000	0.992647	0.999996	0.999763
Female	Coloured	0.694619	0.999176		0.999995	0.997379	1.000000	0.997500	0.991227
Female	Indian/Asian	0.750893	1.000000	0.999995		0.999998	0.999971	0.999980	0.999661
Male	Black	0.000595	1.000000	0.997379	0.999998		0.975562	0.999999	0.999884
Male	White	0.278689	0.992647	1.000000	0.999971	0.975562		0.991045	0.977893
Male	Coloured	0.243844	0.999996	0.997500	0.999980	0.999999	0.991045		0.999999
Male	Indian/Asian	0.300297	0.999763	0.991227	0.999661	0.999884	0.977893	0.999999	

Scheffe Test; Variable Waist Circumference Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.014150	0.088755	0.170644	0.222542	0.891870	0.728934	0.999116
Female	White	0.014150		0.999969	0.997647	0.971655	0.002922	0.999967	0.969932
Female	Coloured	0.088755	0.999969		0.999967	0.944793	0.016795	0.999030	0.937556
Female	Indian/Asian	0.170644	0.997647	0.999967		0.893952	0.043375	0.990742	0.877386
Male	Black	0.222542	0.971655	0.944793	0.893952		0.049751	0.999984	0.999793
Male	White	0.891870	0.002922	0.016795	0.043375	0.049751		0.323793	0.939126
Male	Coloured	0.728934	0.999967	0.999030	0.990742	0.999984	0.323793		0.998729
Male	Indian/Asian	0.999116	0.969932	0.937556	0.877386	0.999793	0.939126	0.998729	

Scheffe Test; Variable Hip Circumference Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.090386	0.253849	0.318350	0.000000	0.011777	0.010652	0.049443
Female	White	0.090386		0.999981	0.997468	0.465666	0.999884	0.824833	0.869052
Female	Coloured	0.253849	0.999981		0.999949	0.939977	1.000000	0.972162	0.974364
Female	Indian/Asian	0.318350	0.997468	0.999949		0.999768	0.999904	0.999617	0.999362
Male	Black	0.000000	0.465666	0.939977	0.999768		0.783230	1.000000	0.999997
Male	White	0.011777	0.999884	1.000000	0.999904	0.783230		0.943253	0.955352
Male	Coloured	0.010652	0.824833	0.972162	0.999617	1.000000	0.943253		1.000000
Male	Indian/Asian	0.049443	0.869052	0.974364	0.999362	0.999997	0.955352	1.000000	

Scheffe Test; Variable WHR Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		1.000000	0.994262	0.988965	0.008997	0.000000	0.906912	0.107784
Female	White	1.000000		0.998093	0.994284	0.152025	0.000018	0.940072	0.173460
Female	Coloured	0.994262	0.998093		0.999998	0.116900	0.000109	0.777282	0.094889
Female	Indian/Asian	0.988965	0.994284	0.999998		0.252878	0.002676	0.777301	0.132196
Male	Black	0.008997	0.152025	0.116900	0.252878		0.209552	0.999698	0.961783
Male	White	0.000000	0.000018	0.000109	0.002676	0.209552		0.431935	0.999990
Male	Coloured	0.906912	0.940072	0.777282	0.777301	0.999698	0.431935		0.917860
Male	Indian/Asian	0.107784	0.173460	0.094889	0.132196	0.961783	0.999990	0.917860	

Scheffe Test; Variable Backrest Point Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.708716	0.978379	0.974913	0.000072	0.998578	0.109801	0.998373
Female	White	0.708716		1.000000	1.000000	0.619218	0.601575	0.828393	0.857560
Female	Coloured	0.978379	1.000000		0.999999	0.775635	0.918245	0.848922	0.949595
Female	Indian/Asian	0.974913	1.000000	0.999999		0.980878	0.921629	0.974371	0.934789
Male	Black	0.000072	0.619218	0.775635	0.980878		0.001403	0.999989	0.172839
Male	White	0.998578	0.601575	0.918245	0.921629	0.001403		0.084096	0.999992
Male	Coloured	0.109801	0.828393	0.848922	0.974371	0.999989	0.084096		0.280106
Male	Indian/Asian	0.998373	0.857560	0.949595	0.934789	0.172839	0.999992	0.280106	

Scheffe Test; Variable Lumbar Support Point Probabilities for Post Hoc Tests									
Sex	Ethnic Groups	Black Female	White Female	Coloured Female	Indian/ Asian Female	Black Male	White Male	Coloured Male	Indian/ Asian Male
Female	Black		0.883038	0.099882	0.135060	0.519907	0.388908	1.000000	0.999936
Female	White	0.883038		0.799715	0.671366	0.134872	0.091171	0.990340	0.972946
Female	Coloured	0.099882	0.799715		0.999828	0.003780	0.002398	0.507277	0.476354
Female	Indian	0.135060	0.671366	0.999828		0.011422	0.007110	0.394910	0.362251
Male	Black	0.519907	0.134872	0.003780	0.011422		0.999964	0.989654	0.999836
Male	White	0.388908	0.091171	0.002398	0.007110	0.999964		0.964459	0.998321
Male	coloured	1.000000	0.990340	0.507277	0.394910	0.989654	0.964459		0.999998
Male	Indian	0.999936	0.972946	0.476354	0.362251	0.999836	0.998321	0.999998	

Scheffe Test; Variable Cushion Probabilities for Post Hoc Tests									
Sex	**Ethnical group**	**Black Female**	**White Female**	**Coloured Female**	**Indian/ Asian Female**	**Black Male**	**White Male**	**Coloured Male**	**Indian/ Asian Male**
Female	**Black**		0.053366	0.647985	0.949050	**0.000002**	0.486361	**0.004918**	0.999922
Female	**White**	0.053366		0.999995	0.999950	0.950997	0.995758	0.786892	0.971811
Female	**Coloured**	0.647985	0.999995		1.000000	0.945307	0.999987	0.770800	0.996309
Female	**Indian**	0.949050	0.999950	1.000000		0.964246	1.000000	0.819203	0.999603
Male	**Black**	**0.000002**	0.950997	0.945307	0.964246		0.494139	0.992050	0.667998
Male	**White**	0.486361	0.995758	0.999987	1.000000	0.494139		0.413896	0.999271
Male	**Coloured**	**0.004918**	0.786892	0.770800	0.819203	0.992050	0.413896		0.455457
Male	**Indian**	0.999922	0.971811	0.996309	0.999603	0.667998	0.999271	0.455457	