THE KINEMATICS OF SUPPORTED AND UNSUPPORTED BREAST DISPLACEMENT DURING STANDARD INCREMENTAL TREADMILL ACTIVITY AND TWO-STEP STAR JUMPING

By

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DEDICATION

TO ALL WOMEN

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SYNOPSIS

Title	**The kinematics of supported and unsupported breast displacement during standard incremental treadmill activity and two-step star jumping**
Candidate	**Sasha Enid Burgoyne**
Promoter	**Dr Kim Nolte**
Degree	**MA (HMS)**

Experts within the health and fitness industry have suggested that active females should wear a well-fitting sports bra in order to reduce pain and motion of the breasts during exercise (Li-xia, Xue-ling & Wei-dong, 2009).

Currently there are two sports bra designs dominating the market. The encapsulating bra for bigger busted women with a cup size C to D who require more support, and the compression bra for smaller busted women with a cup size A to B (Page & Steele, 1999). Encapsulating bras separate and support each breast separately offering more support through moulded cups, while the compression bra restricts, compresses and evenly distributes the breast tissue against the body reducing movement in the breast (White, Scurr & Smith, 2009).

Due to the weak natural support in the breast, physical activity causes independent movement of the breast. This breast displacement has a number of negative consequences. Firstly, exercise related breast pain has been reported in up to 72% of exercising females (Gehlsen & Albohm, 1980). This breast pain is thought to be caused by tension on the supporting structures of the breast (Mason, Page & Fallon, 1999). Secondly, repeated loading to the internal breast support structures may lead to irreversible breast sag (Page & Steele, 1999). Thirdly, breast displacement may have a negative effect on sporting performance by causing changes in the forces acting on the body (White *et al.*, 2009), by effecting breathing mechanics, and by changing technique. Fourthly, it has been anecdotally reported that breast displacement can cause embarrassment, deterring some women from participating in physical activity (Bowles, Steele & Munro, 2008).

The primary aim of the study was to determine how effective the Ultimate shock absorber bra (N04663) (HIU bra) is in reducing breast displacement and improving breast comfort during treadmill running and a Two-Step Star Jump test in relation to a no bra condition (Control), while wearing three different Shock Absorber support level bras as well as participants' own training bra. It was hypothesised that breast displacement would be significantly reduced in all directions during the two activities when wearing the HIU bra in comparison to other bra conditions.

A group of 17 females between the ages of 17-39 years were recruited for the study with a cup size of B-C with no prior surgery to the breast. Participation was voluntary and all participants completed and signed a consent form prior to participation. Each participant was assessed on three occasions. Stature, body mass and breast measurement where recorded followed by the breast displacement measurements (Qualisys Motion Capture System) with six randomly ordered bra conditions during incremental treadmill activity and the Two-Step Star Jump test.

To determine significant differences between test conditions the Wilcoxon signed ranks test and the Friedman test were used for the statistical analysis. The following results were found at the various treadmill speeds. Four sets of data were collected: 1.) Displacement of the right breast in the X (lateral) Plane, Y (anteroposterior) Plane, and Z (vertical or superior-inferior) Plane. 2.) The percent reduction of the right breast in each plane with a Control (no bra condition). 3.) The percent reduction of the right breast in each plane with the participants Own bra and four Shock Absorber bras with varying levels of support including the HIU bra. 4.) The Residual displacement and percent reduction of breast displacement when performing the Two-Step Star Jump test.

Little substantial breast displacement was noted at 4km/h, the HIU bra showed the greatest support in both lateral and anteroposterior displacement in comparison to the Control ($p>0.02$) and Low ($p>0.019$) ($p>0.006$) impact support level bra, with no significant difference ($p>0.05$) found in comparison to the other support level bras. At 6km/h tissue displacement increased and a significant difference ($p<0.05$) was identified between the HIU bra and the High impact support level bra for Residual displacement (Overall displacement). Showing that at 6km/h the HIU bra was most effective in decreasing the amount of Residual displacement. Breast tissue displacement plateaued between 8-10km/h. The HIU bra demonstrated the greatest level of support in the X and Y-Planes in relation to both the Control and the Low impact support level bra at 8km/h. No significant difference ($p<0.05$) was found for the Medium and High impact support level bras or in the other planes of movement. This trend continued for the HIU bra at 10km/h, finding again a significant difference ($p<0.05$) for breast support in comparison to the Control in the Y and Z-Planes, High impact support level bra in the X-Plane, and Own bra in the Z-Plane.

Breast kinematic research has primarily been aimed at treadmill running. Focus has been on vertical displacement of the breast tissue at limited speeds (Bridgman, Scurr, White, Hedger & Galbraith, 2010). One of the aims of this study was to also identify which bra would give the most support during the performance of the Two-Step Star Jump test. Reports have suggested that the Two-Step Star Jump test is a whole body movement exercise and causes excessive movement of the breast tissue and thus can be used as a diagnostic tool to determine the effectiveness of the bra (Bridgman *et al*., 2010). The Two-Step Star Jump test showed similar results to the incremental treadmill running and a statistically significant difference of $p=0.00$ was found between the HIU bra in comparison to the Control as well as between the HIU bra in comparison to the Medium impact support level bra and participants' Own bra in the X-Plane ($p=0.00$). In the Y-Plane a statistically significant difference ($p=0.00$) was found between the HIU bra in comparison to the Control and Medium impact support level bra. In the Z-Plane a statistically significant difference was found with the HIU bra in comparison to the Control, Own bra as well as in comparison with the Low impact support level bra ($p=0.00$). Residual displacement showed a statistically significant difference for the HIU bra compared to all the bras as well as the Control ($p=0.00$), except when compared to the Medium impact support level $p=0.002$. All other bras performed similarly in the three planes with no significant differences found ($p>0.05$). Percent reduction for Residual displacement showed a significant difference in the Two-Step Star Jump test with the HIU bra compared to all the bras as well as the Control ($p=0.00$), while the significant difference for the HIU bra compared to the Medium impact support level was $p=0.002$. All other bras performed similarly in the X-Plane, Y-Plane, and Z-Plane with no significant difference found.

From the results of this study, it appears as if the best breast support during the incremental treadmill activity and Two-Step Star Jump test was achieved while wearing the HIU bra regarding percent reduction (overall reduction in displacement) in all planes of movement and Residual displacement.

Percent reduction was significantly decreased ($p<0.05$) in comparison to the other conditions and demonstrates the ability of the HIU bra to limit the amount of external force acting on the breast tissue in complex whole body movements. This is in line with other studies which have been completed, demonstrating the benefit of wearing a well fitted encapsulating sports bra in reducing breast displacement and discomfort while participating in physical activity (Bowles *et al.*, 2011). This shows that the HIU bra offers the best support not only with treadmill running at different speeds but in a complex whole body movement as well.

Perceptual feedback also indicated that participants felt comfortable in the bra. In addition breast pain was reduced during the activities while wearing the HIU in relation to the other bra conditions and Control. Dislikes in the design were aimed at ill-fitting straps, to tight or too loose as well as the fit around the bust. Thus, it may be beneficial for manufacturers to redesign the bra strap and investigate the elasticity of the fabric (Bowles *et al.*, 2011).

To conclude, the HIU bra provides good breast support for women (bra cup size B-C) during high impact activities. The bra is perceived as comfortable and may reduce breast pain during activity or exercise. For less strenuous or lower impact activities the lower levels support bras may be adequate.

Keywords: breast displacement, treadmill running, Two-Step Star Jump test, breast support, mastalgia.

SINOPSIS

Titel	**Die kinematika van ondersteunde en nie-ondersteunde borsverplasing gedurende die standaard inkrementele trapmeulaktiwiteit en twee-stap stêrspronge**
Candidate	**Sasha Enid Burgoyne**
Promoter	**Dr Kim Nolte**
Graad	**MA (HMS)**

Kenners in die gesondheid- en fiksheidbedryf het voorgestel dat aktiewe vroue 'n goedgepaste sportsbra moet dra om pyn en beweging van die borste te verminder tydens oefening (Li- xia, Xue-ling & Wei-dong, 2009).

Tans is daar twee sportsbra ontwerpe wat die mark oorheers. Die vatbra, vir vroue met meer voller borste, (koppie grootte C tot D) vir diegene wat meer ondersteuning nodig het en die drukbra vir vroue met kleiner borste koppie grootte A tot B (Page & Steele, 1999). Die vatbra besit gevormde koppies wat elke bors afsonderlik skei en ondersteun, terwyl die drukbra die borsweefsel beperk, saampers en eweredig versprei teen die liggaam wat beweging van die borste verminder (White, Scurr & Smith, 2009).

Tydens fisiese aktiwiteit ontwikkel onafhanklike beweging van die borste a.g.v. swak natuurlike borsteondersteuning. Die verplasing van die borste lei na 'n aantal negatiewe gevolge. Eerstens, ‘n pyn in die borste tydens oefening is aangemeld deur 72% fisiese aktiewe vroue (Gehlsen & Albohm, 1980). Die borste pyn is vermoedelik veroorsaak deur spanning op die ondersteunende strukture van die bors (Mason, Page & Fallon, 1999). Tweedens, as gevolg van herhaaldelike lading op die borste se interne ondersteuningstrukture kan daar tot onomkeerbare hang borste gevolg hê (Page & Steele, 1999). Derdens, kan die borsteverplasing 'n negatiewe uitwerking op sportprestasie hê deur veranderlike kragte wat op die ligaam uitwerk (White *et al.*, 2009). Dit is deur die totstandkoming van asemhalingsmeganika en deur die verandering van tegniek. Vierdens is dit berig dat borsteverplasing verleentheid kan veroorsaak wat sommige vroue weerhou van deelname aan fisiese aktiwiteit (Bowles, Steele & Munro, 2008).

Die hoofdoel van hierdie studie was om die doeltreffendeheid van die Ultimate skokbreker bra (N04663) (HIU bra) te bepaal in die vermindering van borsteverplasing en die verbetering van gemaklik m.b.t. borste tydens loop op trapmeule en 'n twee-stap stêrspronge toets. Dit is ten

opsigte van 'n geen-bra toestand as kontrole, terwyl die dra van drie verskillende skokbreker ondersteuningbras asook die ondersoekdeelnemer se eie oefeningsbra. Die hipotese is dat borsteverplasing aansienlik verminder in alle rigtings gedurende die twee aktiwiteite wanneer HIU bra gedra word ten opsigte van die ander twee bra toestande.

'n Groep van 17 gesonde vroue tussen die ouderdom van 17-39 jaar is gewerf vir die studie. Elk het 'n koppie grootte tussen B tot C met geen vorige borstechirurgie. Die vroue is gevra om vrywilliglik deel te neem en ‘n toestemmingsvorm te onderteken. Elke deelnemer is opgemeet op drie punte - postuur, liggaamsmassa en borstemeting. Hul borsteverplasingmetings was opgeneem deur die Qualisys Motion Capture System met ses arbitrêre geplaaste bra posisies. Hierdie metings was geneem gedurende inkrementele trapmeulaktiwiteit en die twee-stap stêrspronge toets.

Die Wilcoxon-ondertekende ranglystoets en die Friedman-toets was gebruik vir statistiese ontleding. Dit was om vas te stel watter beduidende verskille tussen die toets toestande ontstaan. Die volgende vier stelle data was opgeneem by verskillende trapmeule spoed: 1.) Die verplasing van die regterbors in die X (laterale) vlak, Y (anteroposterior) vlak, en Z (vertikaal of superior-inferior) vlakke. 2.) Die verminderingspersentasie van die regterbors in elke vlak met geen bra as kontrole. 3.) Die verminderingspersentasie van die regterbors in elke vlak met die deelnemers se eie bra sowel as vier skokbreker bras (met wisselende vlakke van ondersteuning) en die HIU bra. 4.) Die oortollige verplasing en verminderingspersentasie van borsteverplasing by die verrigtinge van die Twee- Stap stêrsprong toets.

Gedurende die 4km/h studie was daar bevind dat die HIU bra die meeste ondersteunning in beide laterale en anteroposterior verplasing bied in vergelyking met lae impak ondersteuningvlak bra ($p=0.019$) ($p>0.006$) sowel as die kontrole ($p>0.02$). Geen beduidende verskil was gevind in vergelyking met die ander ondersteuningvlak bras nie ($p> 0.05$).

Op 6 km/h het die weefsel verplasing verhoog en 'n beduidende verskil ($p< 0.05$) was geïdentifiseer tussen die HIU bra en die hoë impak ondersteuningvlak bra vir verdere verplasing (algehele verplasing). Borsweefselverplasing het plato tussen 8-10km/h. Die HIU bra het die meeste ondersteuning in die X en Y vlakke in verhouding tot beide die kontrole en die lae impak ondersteuningvlak bra getoon by 8km/h.

Geen beduidende verskil ($p< 0.05$) was gevind vir die medium en hoë-impak ondersteuningvlak bras nie. Hierdie tendens gaan voort vir die HIU bra teen 10 km/h, waar ‘n beduidende verskil in bors ondersteuning ten opsigte van kontrole gesien is in die X- en Y-vlakke, waar die hoë impak ondersteuningsvlak bra in die X- vlak is en deelnemer se eie oefeningsbra in die Z- vlak is.

Kinematiese borstenavorsing is hoofsaaklik gemik op trapmeuloefeninge. Fokus is geplaas op vertikale verplasing van die borsweefsel teen beperkte spoed (Bridgman, Scurr, White, Hedger & Galbraith, 2010). Een van die doelwitte van hierdie studie was ook om te identifiseer watter bra die meeste ondersteuning sal bied tydens die uitvoering van die twee-stap stêrsprong toets. Navorsing het aangedui dat die twee-stap stêrsprong toets die hele liggaam beoefen. Die toets veroorsaak oormatige beweging van die borsweefsel en kan dus gebruik word as 'n diagnostiese instrument om die doeltreffendheid van die bra te bepaal (Bridgman *et al.*, 2010). Die twee-stap stêrsprong toets het soortgelyke resultate getoon teenoor die inkrementele trapmeule loop. Daar is 'n statisties beduidende verskil van p= 0.00 gevind tussen die HIU bra in vergelyking met die kontrole asook tussen die HIU bra in vergelyking met die medium impak ondersteuningvlak bra en deelnemers se eie bra in die X- vlak (p= 0.00). In die Y- vlak is 'n statisties beduidende verskil (p= 0.00) gevind tussen die HIU bra in vergelyking met die kontrole en medium impak ondersteuningvlak bra.

In die Z-vlak was 'n statisties beduidende verskil gevind met die HIU bra in vergelyking met die kontrole, die deelnemer se eie oefeningsbra sowel as in vergelyking met die lae impak ondersteuningvlak bra (p = 0.00). Oorblywende verplasing het 'n statisties beduidende verskil getoon vir die HIU bra in vergelyking met al die bras sowel as die kontrole (p= 0.00), behalwe wanneer dit vergelyk word met die medium impak ondersteuningvlak (p= 0.002). Alle die ander bras het soortgelyk presteer in die vlakke met geen beduidende verskille nie (p> 0.05). Verminderingspersentasie vir oortollige verplasing het 'n beduidende verskil in die twee-stap stêrsprong toets met die HIU bra gewys in vergelyking met al die bras sowel as die kontrole (p= 0.00), waar ‘n beduidende verskil van p= 0.002 vir die HIU bra in vergelyking met die medium impak ondersteuningvlak bra getoon was. Alle die ander bras het soortgelyk presteer in die X-, Y- en Z-vlak met geen beduidende verskille nie.

Uit die resultate van hierdie studie blyk dit asof die beste borsteondersteuning voorsien word deur die dra van die HIU bra gedurende die inkrementele trapmeule toets en twee stap stêrsprong toets i.v.m verminderingspersentasie (algehele afname in verplasing) in alle vlakke van beweging en oorblywende verplasing.

Verminderingspersentasie het beduidend afgeneem (p< 0.05) in vergelyking met die ander toestande en demonstreer die vermoë wat die HIU bra het om die aantal eksterne kragte te verminder wat op die borsweefsel inwerk gedurende ingewikkelde volle liggaamsbewegings.

Dit is in lyn met ander studies wat reeds voltooi is, wat toon dat: om ‘n welpassende en omvattende sportsbra te dra, verminder dit borsteverplasing en ongemaklikheid tydens die deelname aan fisiese aktiwiteit (Bowles *et al.*, 2011). Dit wys dat die HIU bra bied die beste ondersteuning in beide trapmeule aktiwiteit teen verskillende snelhede sowel as komplekse volliggaam bewegings.

Meningsterugvoer deur die deelnemers het ook aangedui dat hulle gemaklik voel wanneer hulle die HIU bra.

Met die dra van die HIU bra was borstepyn verminder tydens die aktiwiteite in verhouding tot die ander bratoestande en die geen-bra kontrole.

Afkeure in die ontwerp was bande wat te knap sit, ‘n te styf of te los gevoel in die bras en hoe dit pas rondom die buuste. Dus kan dit voordelig wees vir bravervaardigers om ‘n herontwerp in die braband te ondersoek so-ook die elastisiteit van die materiaal van die braband (Bowles *et al.*, 2011).

Ter slotte: Die HIU bra bied 'n goeie borsteondersteuning vir vroue met ‘n borstegrootte van koppiegrootte tussen B-C tydens hoë impak aktiwiteite. Die bra word beskou as gemaklik en kan borstepyn verminder gedurende liggaamsaktiwiteit of oefening. Vir minder veeleisende of laer impak aktiwiteite kan die laer ondersteuningsbras ook voldoende wees.

Sleutelwoorde: borsteverplasing, trapmeulhardloop, twee-stap stêrsprong toets, borste ondersteuning, mastalgie.

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LIST OF ABBREVIATIONS

FSH - Follicle stimulating hormone

HIU - Ultimate shock absorber bra

LH - Leutenising hormone

MMPs -Matrix metalloproteinases

ECM -Extracellular matrix

ISAK-International Society for the Advancement of Kinathropometry

CHAPTER ONE: THE PROBLEM

1.1 INTRODUCTION

Experts within the health and fitness industry have suggested that active females should wear a well-fitting sports bra in order to reduce pain and motion of the breasts during exercise (Li-xia *et al.*, 2009). It has been found that up to 75% of females do not wear the appropriate sportswear and are unaware of how to correctly choose a sports bra (Li-xia *et al.*, 2009). Although vertical breast displacement and velocity have been associated with breast pain, the influence of breast comfort and kinematics has yet to be ascertained (Scurr, White & Hedger, 2010).

Biomechanical evaluation involving the measurement of breast displacement and using the Qualisys Motion Capture Analysis system, allows us a better understanding of the kinematics of the breast and the support needed. Such information will aid in the development of improved bra design, as manufacturers move toward activity-specific bra design (Scurr *et al*., 2010). Retro reflective marker will be placed on the right nipple, suprasternal notch, and the anteroinferior aspects of the 10th ribs to establish the control. During the bra conditions markers will be repositioned on the bra over the nipple (Scurr *et al*., 2010). These markers will give a reference point to determine breast displacement and percentage of breast displacement reduction. A standard incremental treadmill test and Two-Step Star Jump test will be used to prompt breast displacement. Performing the Two-Step Star Jump test is a valuable test or movement to analyse with regards to breast displacement, as it is a dynamic whole body movement (Stamford, 1996). Participants will also be required to rate their overall breast comfort using the visual analog scale for breast comfort (Mason *et al.*, 1999).

Currently there are two sports bra designs dominating the market. The encapsulating bra for bigger busted women with a cup size C to D who require more support; and the compression bra for smaller busted women with a cup size A to B (Page & Steele, 1999).

Encapsulating bras separate and support each breast separately offering more support through moulded cups, while the compression bra restricts, compresses and evenly distributes the breast tissue against the body reducing movement in the breast (White *et al*., 2009). Once the breast tissue is held firmly to the body the bra attempts to limit the amount of movement by restricting the boundaries in which the breast is able to move. Most sports bras are anchored to the body by strong elastic or under wire beneath the breast (Page & Steele, 1999). Additional designs may include a higher neckline anchored with strong elastic to limit upward motion of the breast.

Fabric choice of the bra also plays a great role in the support of the breast. Sports bras are designed to be used in activities that use upper body movement and may induce perspiration. Consequently fabrics used in the manufacturing of bras need to have the correct mechanical properties such as elasticity to enable upper torso movement and plasticity to prevent breast movement while still allowing the breast to 'breath' (Page & Steele, 1999). However no matter how good the design of the bra, if it is the incorrect fit or size the bra will not offer the correct support required and is ineffective (Page & Steele, 1999). The inability to find a good supportive bra could lead to breast discomfort, non-participation in sport with poor adherence to exercise as well as the irreversible breakdown of breast tissue (White *et al*., 2009).

Research has shown that in long term exposure to stimuli which disrupt intercellular signals defining the structural context of a cell leads to the disruption of epithelial tissue. As such this leads to the disruption of the epithelial sheet and proliferation: for example after activation of mesenchymal fibroblasts due to wounding. This is temporary and reversible in most instances, however when the inflammation is sustained a rising feedback loop ensues. Under such conditions there is a constant up regulation of enzymes such as matrix metalloproteinases (MMPs) via the stromal fibroblasts which disrupt the extracellular matrix (ECM) (Bissell & Radisky, 2001). Through this disruption immune cells overproduce factors that may stimulate abnormal cell proliferation.

The relationship between cells and their micro- and macro environments creates a framework that promotes tumour growth and protects against immune attack (Bissell & Radisky, 2001). As malignancy progresses, surrounding tissues change to adapt to the functional association of cancer cells. Under normal conditions the organs in the body are made up of tissues that are able to interact and communicate with other cells and tissue types via cytokines and the ECM. The ECM provides structural scaffolding for cells provided by the interaction of the stromal fibroblasts and the epithelial cells. The endothelial vasculature provides oxygen and nutrients while cells of the immune system combat pathogens and aid in the removal of apoptotic cells.

Epithelial cells are arranged as polarised intact sheets and communicate via a complex network of interactions including direct physical contact with the intervening ECM and biomechanically through soluble and insoluble signalling molecules (Bissell & Radisky, 2001). These interactions are necessary in providing information for maintaining complex tissue structures and cellular differentiation (Bissell & Radisky, 2001). This gives further encouragement to women to wear the correct breast support during exercise, possibly aiding the prevention of breast cancer, as exercise disrupts the breast tissue. More research is needed in this area and will not be covered in the scope of this study.

It is expected that bare-breasted running causes a great deal of disruption to the cells of the breast along with discomfort up to a certain velocity with the greatest vertical displacement and maximum downward deceleration force on the breast (White *et al*., 2009). It is important for women to understand the movement of the breast is not only a vertical movement but is three-dimensional. This is described as six degrees of freedom: namely the ability of the breast to move in three directions anteriorly/posteriorly, superiorly/inferiorly, medially and laterally (White *et al.*, 2009; Zhou, Yu & Ng, 2012*)*. Thus awareness of the impact of different modes of exercise and activity on the breast with different support modes and the risk to injury, breast discomfort and exercise performance is important for all women (White *et al*., 2009).

1.2 PROBLEM SETTING

Due to the weak natural support in the breast, physical activity causes independent movement of the breast. This breast displacement has a number of negative consequences. Firstly, exercise related breast pain has been reported in up to 72% of exercising females (Gehlsen & Albohm, 1980). This breast pain is thought to be caused by tension on the supporting structures of the breast (Mason *et al.*, 1999). Secondly, repeated loading to the internal breast support structures may lead to irreversible breast sag (Page & Steele, 1999). Thirdly, breast displacement may have a negative effect on sporting performance by causing changes in the forces acting on the body (White *et al*., 2009), by effecting breathing mechanics, and by changing technique. Fourthly, it has been anecdotally reported that breast displacement can cause embarrassment, deterring some women from participating in physical activity (Bowles, Steele & Munro, 2008).

Research in the area of breast biomechanics is focused on kinematics of the breast during different activity types (Haake & Scurr, 2010). It has been considered that in order to determine if a bra is effectively designed for the activities carried out, the mechanical properties of the breast should be established (Haake & Scurr, 2010). Thus a model of the breast/bra system may help bra designers in the creation of harmonic motion between the breast and the trunk during physical activity (Haake & Scurr, 2010).

Proper bra design is essential due to the increase of female participation in sporting activities as it will provide optimum breast support and reduce the implications of non-participation in physical activity as a result of breast displacement and pain (Bridgman *et al*., 2010).

This study will look at identifying how different levels of support influence breast displacement during treadmill running and Two-Step Star Jumping. This research can be used to help promote awareness for the correct fit and use of a sports bra.

1.3 PURPOSE AND AIM OF THE STUDY

The primary aim of the study was to determine how effective the Ultimate shock absorber bra (N04663) (HIU bra) is in reducing breast displacement and improving breast comfort during treadmill running and a Two-Step Star Jump test in relation to a no bra condition (Control), while wearing three different Shock Absorber support level bras as well as participants' own training bra.

Additional aims of the study were as follows:

- Biomechanically assess breast displacement (wearing no bra) during walking/running on the treadmill and while performing the Two-Step Star Jump.
- Biomechanically assess breast displacement (wearing the Ultimate Shock Absorber bra (N04663), three different Shock Absorber support level bras as well as participants' own training bra) during walking/running on the treadmill and while performing the Two-Step Star Jump.
- Compare breast displacement during the no bra condition and while wearing the Ultimate Shock Absorber bra (N04663), three different Shock Absorber support level bras and participants own training bra.
- Assess and compare breast comfort during each condition by means of a questionnaire.
- Make recommendations regarding which bra is most effective in reducing breast displacement and improving breast comfort during physical activity such as running and jumping.

We aimed to quantify breast displacement against a Control and determine the efficiency of breast support in reducing breast displacement with physical activity such as the running gait and jumping. This research may assist manufactures with insight to the design of sports bras in different movement patterns that more effectively reduce breast displacement and pain.

The research design used is a cross-sectional experimental study. Non-parametric statistic are used as a result of the atypical data distribution (See Chapter 3).

Ethical clearance was obtained from the Postgraduate and Ethics Committee of the Faculty of Humanities, University of Pretoria, South Africa. Participation was voluntary and all participants completed and signed a consent form prior to participation in the study. Testing took place in a controlled environment with only three female researchers present in a private room with one participant at a time due to the sensitive nature of the study.

Participants were required to be female, between the ages of 17-39 years and with a Cup size B-C. Concerns for the population included that all participants would be required to be familiar and comfortable with treadmill running, this narrowed the population down to more athletic women which could give skewed results as more athletic women commonly have a smaller bust and therefore less forceful displacement of breast tissue with activity.

1.4 HYPOTHESIS

The following hypotheses are related to the purpose of the study:

- Breast displacement is significantly reduced in all directions during a standard incremental treadmill test when wearing the new Ultimate Shock Absorber bra (N04663) in comparison to a no bra condition.
- Breast displacement is significantly reduced in all directions during a standard incremental treadmill test when wearing the new Ultimate Shock Absorber bra (N04663) in comparison to three different Shock Absorber support level bras.
- Breast displacement is significantly reduced in all directions during a standard incremental treadmill test when wearing the new Ultimate Shock Absorber bra (N04663) in comparison to the participants own training bra.
- Vertical breast displacement is significantly reduced during the Two-Step Star Jump test when wearing the new Ultimate Shock Absorber bra (N04663) in comparison to a no bra condition.

- Vertical breast displacement is significantly reduced during the Two-Step Star Jump test when wearing the new Ultimate Shock Absorber bra (N04663) in comparison to three different Shock Absorber support level bras.
- Vertical breast displacement t is significantly reduced during the Two-Step Star Jump test when wearing the new Ultimate Shock Absorber bra (N04663) in comparison to the participants own training bra.
- There is a correlation between breast displacement and treadmill speed (as the speed increases so will breast displacement up to a certain level).
- Bra/breast comfort and support ratings during treadmill running in the new Ultimate Shock Absorber sports bra will be higher than when wearing the three different Shock Absorber support level bras, with the participants own training bra as well as the no bra condition.

CHAPTER TWO: LITERATURE REVIEW

2.1 THE BREAST

2.1.1 DEVELOPMENT OF THE BREAST

The development of the breast is a vital part in the human female. Human females unlike other mammals begin breast development as early as five weeks in the womb and long before they need to nurse their offspring (Ellis, 2006). The mammary gland is an organ unique to mammals with the specific function of producing, secreting and delivering milk to the new-born. In the human female the stages of development of the mammary gland are characterized by changes in composition, function and architecture, all mediated by gene expression. Breast development occurs in distinct stages; Firstly before birth (foetal growth), followed by infant (pre-pubertal) growth, pubertal expansion and menstruation, pregnancy and lactation remodelling, and lastly post-lactation and post-menopausal involution. (Ellis, 2006; Hassiotou & Geddes, 2013).

The initial stage of development commences at five weeks in the human foetus, an ectodermal ‘milk streak’ (the mammary ridge) develops along the trunk of either side from the axilla to the groin. By the time a female infant is born the mammary ridge regresses to a definite site of the adult nipple. This forms the beginning of specialized cells known as the epithelium buds which further branch into 15-24 lobes. The first lobes consist of solid epithelium columns and canalize before birth to form lactiferous ducts. At the point of invagination of epithelium from the skin, there is initially a small mammary pit. At the time of birth the nipple will evaginate itself to form a definite nipple. Failure to do so will result in a congenitally inverted nipple which is not uncommon and may be bilateral or unilateral. The epithelial system will then become surrounded by invading mesenchyme; this develops into the supporting connective tissue and fat of the breast (Ellis, 2006).

Stages of development:

a) During weeks 7-8 of gestation the mammary crest is formed as mammary parenchyma invades the stroma. There is a basement membrane which separates the parenchyma form the ectodermal cells. At 10-12 weeks mammary epithelial buds begin to form. This phase is the start of differentiation patterns where subtle difference between male and female can be identified. The areola and smooth musculature start to develop between weeks 12-16, following this at week 13-20 invagination of the areola occurs. From birth to puberty, the breast is composed of lactiferous ducts with no alveoli. At puberty these ducts start to proliferate with their terminations forming a solid mass of cells - the future breast lobules (Hassiotou & Geddes, 2013).

Preadolescent development manifests when the nipple or specifically the papilla start to elevate above the chest wall, there is still however no breast tissue at this stage. This stage of development can start as early as eight years old or up to thirteen years depending on the genetic makeup of the individual (Ellis, 2006). See Figure 2.1.

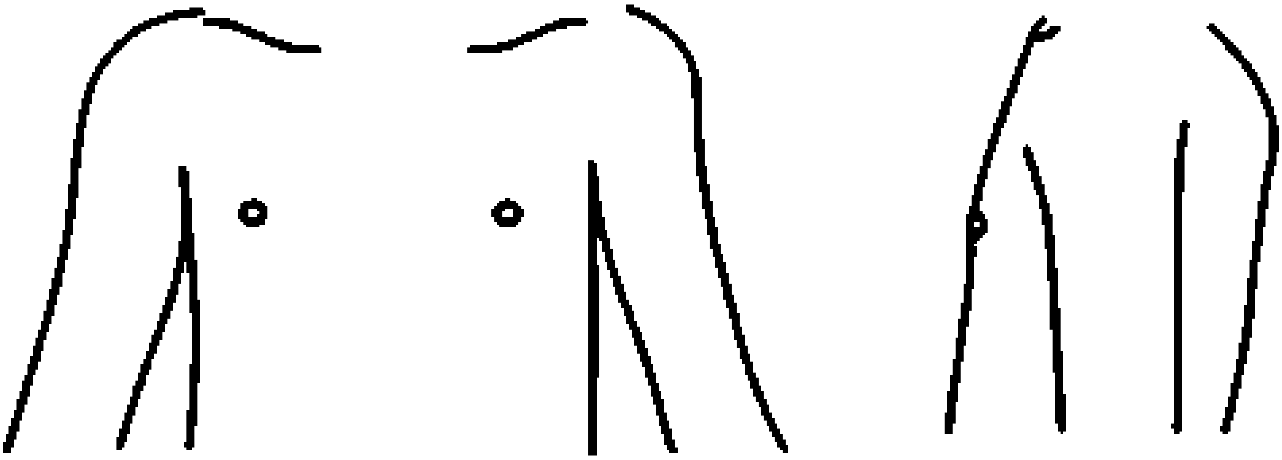


Figure 2.1: Stage 1 of Female breast development (Growbreastnaturally, 2013).

Breast budding is the next stage of development where milk ducts and fat tissue form, causing the breast to lift along with the budding of the nipple. Growth at first is slow and un-noticeable, with the nipple area described as looking swollen. Girls may often start to feel tenderness and pain in the breast at this stage particularly on palpation (Figure 2.2).

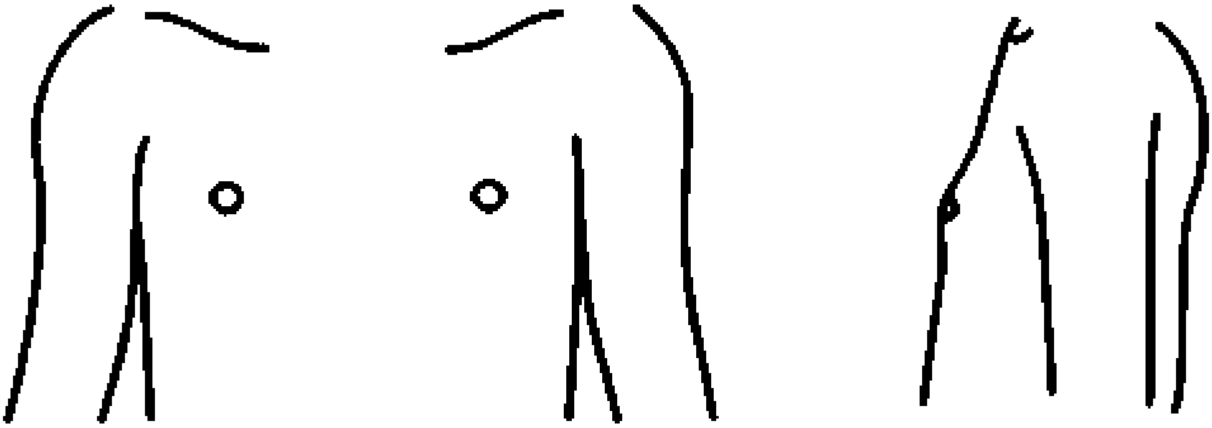


Figure 2.2: Stage 2 of Female breast development (Growbreastnaturally, 2013).

The underlying fat of the breast will start to increase starting in a conical shape and progressing to a rounder shape. At this point there is still no separation of contours and no projection of the nipples. The areola will start to darken at this stage and still appears swollen (Figure 2.3).

Figure 2.3: Stage 3 of Female breast development (Growbreastnaturally, 2013).

As the areola and nipple start to project the next stage of development has been reached. This stage signifies the separation of contours of the breast. As hormonal changes continue, particularly levels of oestrogen, the breasts continue to grow as adipose tissue is deposited and milk ducts are formed. At the point of menarche progesterone is produced by the ovaries and aids in the continual development of the breasts.

Progesterone is responsible for further development and growth of the milk ducts and glands of the breast and does not contribute to any significant increase in breast size. See Figure 2.4.

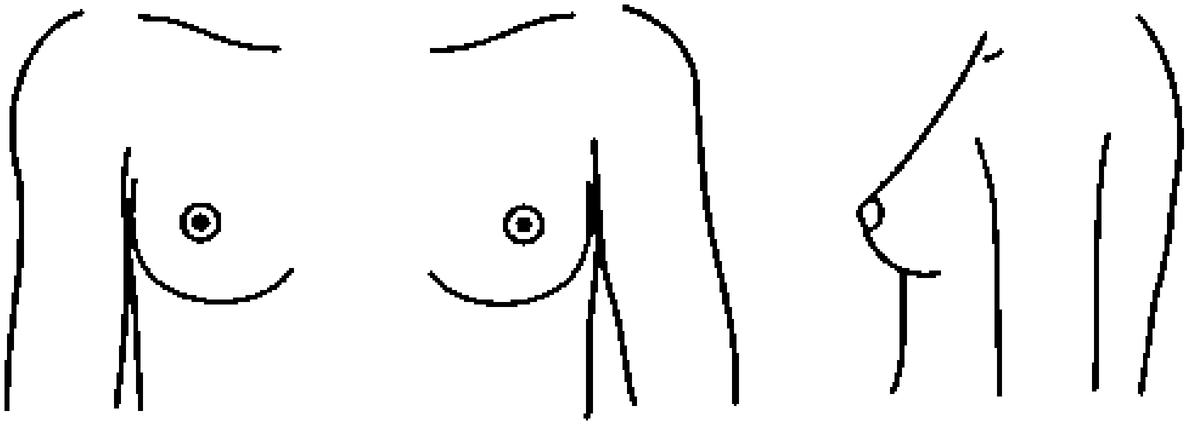


Figure 2.4: Stage 4 of Female breast development (Growbreastnaturally, 2013).

Approximately 3-5 years after the first stage of development has begun the breast will be at its maturity. At this stage the areola will recede leaving the nipple or papillae to extend above the contour of the breasts. Full maturity is only reached in pregnancy where the breast undergoes further remodelling via changes in circulating hormonal complexes in preparation for lactation. Ductal branching, alveolar morphogenesis and secretory differentiation are initiated (Ellis, 2006; Hassiotou & Geddes, 2013).

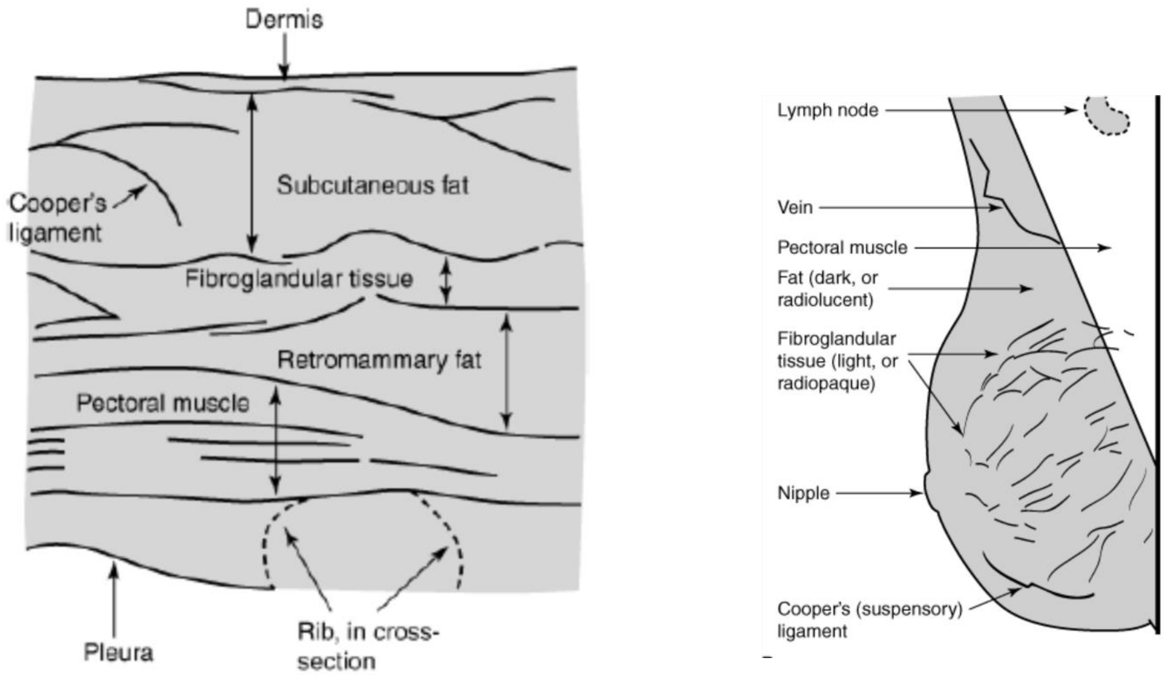
b) During pregnancy secreting alveoli appear. During the early weeks lobular proliferation and ductal sprouting will occur with an increase in the pigmentation of the nipple and the alveoli. The alveoli will now show a lumen surrounded by secretory cells. In the last stages of pregnancy the breasts will secrete colostrum, a yellow, sticky, serous fluid. This will then be replaced by true secretions of milk. Approximately 48-72 hours postpartum milk secretion increases as there is a drop in circulating progesterone and increase in prolactin levels. When lactation ceases the glandular tissue will return to its resting state (Ellis, 2006; Hassiotou & Geddes, 2013).

c) During menopause the glandular tissue of the breast atrophies while the surrounding adipose tissue increases and the connective tissue becomes less cellular with a decrease in collagen (Ellis, 2006; Hassiotou & Geddes, 2013).

2.1.2 THE ANATOMY OF THE BREAST

The breasts are frequently reffered to as sweat glands and are secondary reproductive glands of ectodermal origin. Breasts are the organs of lactation in women and lie on the superior aspect of the chest wall. In men the breast are undeveloped and normally functionless (Karam,2013).

There are three major structural components within the breast: the skin, the subcutaneous tissue and the corpus mammae. The structures that would remain if the breast tissue were to be excised are the corpus mammae along with the subcutaneous tissue and adipose tissue. Figure 2.5 shows the skin, premammary and retromammary fasciae, pectoral fasciae, trabeculae, as well as the duct wall and vessels (Freimanis & Ayoub, 2004). The corpus mammae is the functional part of the breast, a section which can be further broken down into two subcomponents: the parenchyma and the stroma. The parenchyma is comprised of the ductular, lobular and alveolar structures, size varies from one to several millimetres. The parenchymal tissue is situated between the premammary and retromammary fascia. The stroma is comprised of the connective tissue, lymphatics, adipose tissue, blood vessels and nerves (Page & Steele, 1999; Freimanis & Ayoub, 2004). Trabecular structures can measure smaller than one millimetre and give the breast their characteristic shape particularly the Copper's Ligaments curving around the fat lobules along the skin parenchyma. Fat is distributed in the subcutaneous layer and in the retromammary space anterior to the pectoralis muscle (Freimanis & Ayoub, 2004). See Figure 2.5.



<u>Figure 2.5</u>: Normal structures of the breast tissue (Freimanis & Ayoub, 2004).

a) THE BREAST MOUND

The bulk of the breast tissue in an adult female is localized to the upper outer quadrant of the mound. The mound of the breast extends from above the second rib to below the sixth rib. Laterally it reaches the mid axillary line; medially bordering the lateral edge of the border of the sternum. At its superolateral extremity, the breast tissue extends into the axillary region along the lower border of the pectoralis major muscle (the axillary tail of Spence). Each breast rests on the pectoralis major and minor muscles, and is given shape and support by internal suspensory ligaments (Mason *et al.*, 1999; Ellis, 2006 Parker, 2009) (Figure 2.6). The shape and size of the female breasts vary. As a norm most breasts have been reported as measuring 10-12cm in diameter with a central thickness of 5-7cm. Each breast weights approximately 200g with the left breast often being slightly larger than the right. Differences in breast size are attributed to variations in the amount of adipose tissue in the breast (Page & Steele, 1999).

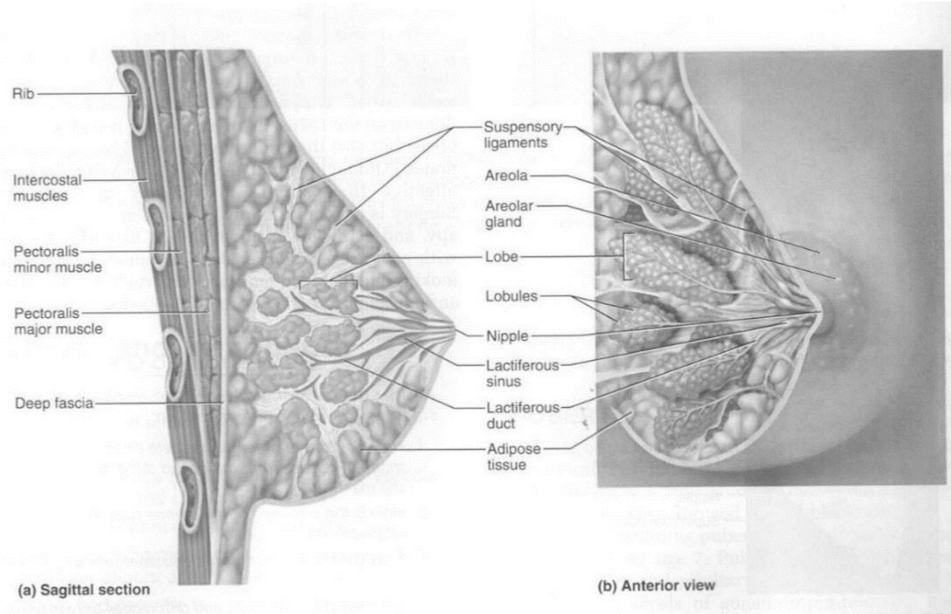


Figure 2.6: Anatomy of the breast. (a) Sagittal section. (b) Surface anatomy and cutaway view of the lobes of mammary gland; anterior view of the right breast (Saladin, 2009).

b) THE NIPPLE

In nulliparous women the nipple is situated at the fourth intercostal space but may be inconstant in relation to the intercostal space when the breasts are pendulous. The nipple is composed of longitudinal and horizontal smooth muscle fibres leading to the nipple base. These fibres either remain separate or intermix with the nipple ducts which are 0.5mm in diameter (Hassiotou & Geddes, 2013). The Breast contains modified sweat glands called mammary glands, which produce milk at childbirth. These mammary glands are composed of 15-24 lobes with a diameter of 0.12mm which are arranged like the petals of a daisy. Each lobe has smaller lobules that end in a bulb. A meshwork of loose, fatty areolar tissue holds the lobules in place. The fatty tissue increases toward the periphery of the lobule and gives the breast its hemispheric shape and bulk (Karam,2013).

The cells of these glands secrete milk, which flow along merging lactiferous ducts towards the nipple (Ellis, 2006; Parker, 2009; Hassiotou & Geddes, 2013). In the non-lactating breast alveoli will be small and tightly packed. During pregnancy the alveoli will hypertrophy and proliferate in number, the secretion of protein and lipid from theses gland comprise breast milk (Karam,2013).

The 15-24 lactiferous ducts open onto the nipple which is surrounded by the areola. The areola is a circular pigmented zone varying in colour from pale pink to brown, depending on age and skin pigmentation (Karam, 2013). The areola consists of large sebaceous glands that often can be seen with the naked eye (the glands of Montgomery). The glands are responsible for lubrication of the nipple to help prevent fissures and cracking while breast feeding (Karam, 2013). Adipose tissue comprises the remainder of the breast tissue (Ellis, 2006).

c) BENEATH THE BREAST

Approximately 80–85% of the normal breast is comprised of adipose tissue. The breast tissues are joined to the overlying skin and subcutaneous tissue by fibrous strands (Karam, 2013). The majority of the breast, approximately two-thirds, lies on the pectoralis major muscle. Laterally the breast tissue overlaps on to the serratus anterior muscle while inferiorly it abuts on to the most superior part of the rectus sheath. The relationship of the breast tissue to the facial sheath is of practical importance. The glands lie in a pocket of superficial fascia. These fibrous processes extend out to the skin and to the nipple and are more developed over the upper part of the breast forming the supporting ligaments of Cooper. The connective or fibrous tissue in the stroma of the breast referred to as the Cooper's ligaments are located within the superficial fascia and separate the breast lobules (Mason *et al*. 1999). These ligaments offer limited support as they attach to the deeper fascia overlying the pectoralis major muscle (Page & Steele, 1999). The deeper layer of superficial fascia is thicker than the subcutaneous component and covers the deep aspect of the breast plate (Ellis, 2006).

Beneath this sheath a filmy layer of areola tissue allows the breast to move freely on the underlying fascial covering of both the serratus anterior and pectoralis major muscles. This areola layer forms the retromammary space (Ellis, 2006).

d) BLOOD SUPPLY

The largest vessels arise from the internal thoracic artery; perforating branches enter the chest wall adjacent to the sternal edge in the first to fourth intercostal spaces. These four branches are the:

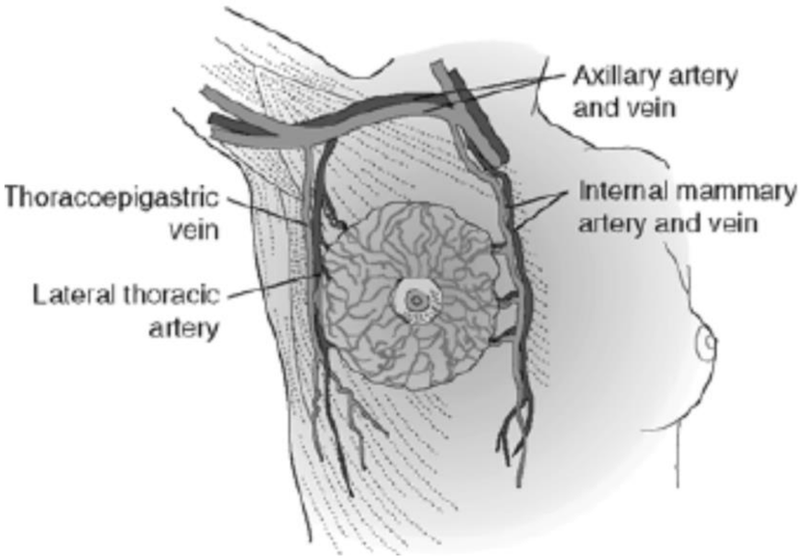
- Superior thoracic
- Pectoral branch of the acromiothoracic

- Lateral thoracic
- Subscapular

Accompanying these arteries are the corresponding veins (Ellis, 2006).

A rich anastomotic network of blood vessels supply the breast derived from the axillary, internal thoracic and intercostal arteries. Blood vessels and capillaries are housed within the stromal matrix and deliver necessary biochemical and cellular components essential for the milk synthesis and gland functionality (Hassiotou & Geddes, 2013). Penetrating the second to fifth intercostal spaces the internal thoracic/mammary artery supplies blood to the medial half of the breast. These arteries perforate both the intercostal muscles and the intercostal membrane to supply the breast as well as the pectoralis major and minor muscles (Karam, 2013). Blood is also supplied to the medial aspect of the breast via smaller branches of the anterior intercostal arteries, pectoral branch of the thoracoacromial branch of the axillary artery and the external mammary branch of the lateral thoracic artery. The external mammary branch of the lateral thoracic artery also forms the second segment of the axillary artery supplying the breast with blood. The external mammary artery passes on the lateral edge of the pectoralis major muscle to supply the lateral half of the breast and is located medially to the thoracic nerve (Karam, 2013). The medial and lateral arteries branch out freely in the supra-areolar area as they reach the breast, subsequently arterial blood supply to the upper half of the breast is almost twice than that of the lower half (Karam, 2013). See Figure 2.7.

Venous return from the breast closely follows the arterial system. Blood is returned to the superior vena cava via the axillary and internal thoracic veins. Intercostal and azygos veins feed into the vertebral venous plexuses and lead to superficial breast veins located in the subareolar region. Venous return flow is greater in the upper quadrants of the breast (Karam, 2013).



<u>Figure 2.7</u>: Blood supply of the breast (Karam, 2013).

e) LYMPHATIC DRAINAGE

The lymphatic drainage of the breast along with the anatomy of the axillary and internal thoracic lymph nodes is of great importance as waste products are lead away. The axillary lymph nodes vary in number of 20-30 and are subsequently divided into five indistinct anatomical groups. Efferents from the apical nodes merge into the subclavian trunk. On the left the trunk drains directly into the thoracic duct while on the right side the subclavian trunk empties into the jugulosubclavian junction. A few efferent channels reach the inferior deep cervical nodes directly. Approximately 75% of all lymphatic drainage of the breast passes to the axillary nodes (Parker, 2009).

Knowledge of lymphatic drainage of the breast is important for clinicians as lymphatic drainage has significant implications on several disease aetiologies including breast cancer. There are two categories of lymphatic drainage in the breast. Firstly superficial drainage which includes cutaneous drainage. Deep to the nipple areolar complex a large lymphatic plexus exits in the subcutaneous tissues of the breast. The plexus drains the areola and nipple area including the cutaneous and subcutaneous tissues. The superficial plexus also drains the deep central parenchymatous region of the breast. Second is the deep parenchymatous drainage, draining the remainder of the breast along with a portion of the skin and subcutaneous tissues of the nipple (Karam, 2013). Lymph from the cutaneous and nipple-areolar region drain directly into the subareolar plexus or alternatively deep into the parenchymatous lymph system. Lymph will then be delivered to the subarelor plexus for efferent transport (Karam, 2013). In general drainage of the breast is to the anterior axillary or subpectoral nodes, located close to the lateral thoracic artery and deep to the lateral border of the pectoralis major muscle. From these nodes, lymph will then travels to nodes in close proximity to the lateral portion of the axillary vein. Lymph then passes superiorly via the axillary chain of lymph vessels and nodes to reach the highest nodes of the axilla (Karam, 2013).See Figure 2.8.

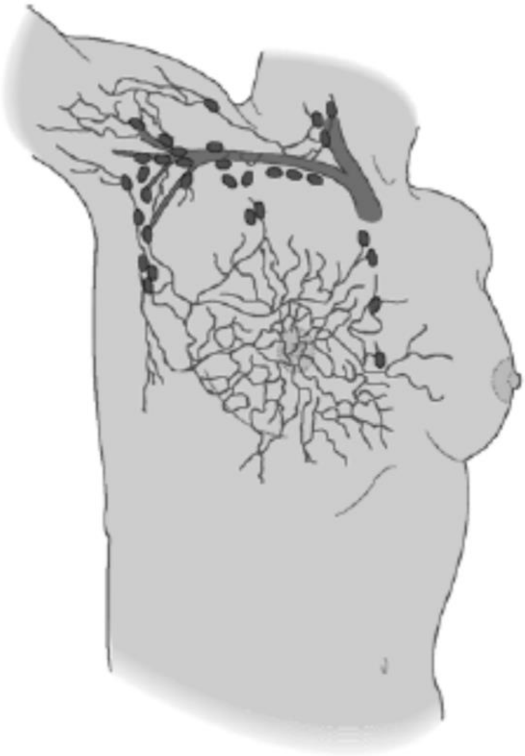


Figure 2.8: Lymphatic drainage of the breast (Karam, 2013).

2.1.3 CYCLICAL CHANGES OF THE BREAST DURING MENSTRATION

A eumenorrheic or normal menstrual cycle runs over a 26-35 day period. The menstrual cycle characterises the reproductive time-span in females from menarche through to menopause. Depending on the individual, cycle rhythms may vary according to how reproductive hormones respond to diet, exercise and other external factor including circadian rhythms (Dawson & Reilly, 2009).

The menstrual cycle can be dived into two phases riven by ovulation. The initial phase is monopolized by the anterior pituitary hormones follicle stimulating hormone (FSH) and leuteinising hormone (LH) this is known as the follicular stage or proliferative phase. FSH is released into the system via a hypothalamic factor and in turn initiates the release and growth of a follicle in the ovary. The ovary will secrete oestradiol in response to elevated levels of FSH and LH, peaking 24 hours before ovulation. The second phase, the luteal phase (secretory phase) is characterised by the increase in oestrogen and progesterone, which are ovarian steroid hormones. After ovulation the cells remaining in the ovary will produce oestradiol and progesterone, creating a negative feedback axis to inhibit further production of FSH and LH. At this point if the ovum has not been fertilised the corpus luteum regresses and the cycle is repeated, see Figure 2.9 (Dawson & Reilly, 2009).

Each month the female adult will experience the above fluctuations in hormones that comprise the normal menstrual cycle. Oestrogen produced by the ovaries in the first half of the menstrual cycle stimulates the growth of milk ducts in the breast. The increasing level of oestrogen leads to ovulation mid-way through the cycle. As the hormone progesterone takes over the second half of the cycle commences and stimulates the formation of the milk glands. The changes in these hormones during the menstrual cycle are responsible for cyclical changes such as swelling, pain and tenderness that women may experience before menstruation (Ellis, 2006; Hassiotou & Geddes, 2013).

The growth of normal breast epithelial cells are also controlled by ovarian steroid hormones oestrogen and progesterone as well as cytokines, suggesting that there are multiple receptor signalling pathways involved in the differentiation and growth of the breast tissue (de Lima, de Amrimatéa dos Santos Junior, Nazário & Michelacci, 2012). Females between the ages of 15-25 years are at a higher risk of developing a breast tumour (fibroadenoma) at this stage of development while the leading feature of breast development is the addition of lobular structures to the duct (de Lima *et al.*, 2012). Over stimulation will cause proliferation of duct like spaces surrounded by fibroblastic stroma (Figure 2.9) (de Lima *et al.*, 2012).

Figure 2.9: Optical microscopy of fibroadenoma and adjacent normal breast tissue during proliferative and secretory phase in the menstrual cycle (de Lima *et al.,* 2012).

It is essential for the healthy development of females that one's cycle have a rhythm and is consistent, failure to establish such a cycle may be detrimental. Female athletes need to be educated about the effects of exercise on the menstrual cycle as there are many misconceptions (Harber, 2011). Currently there has not been enough research done to equivocally show that exercise during menstruation either relieves any discomfort or pain, as well as no substantial evidence to claim an increase in muscular strength or endurance at ovulation, as has been speculated (Bambaeichi, Reilly, Cable & Giacomoni, 2004). Significant research has however been conducted showing the risk of excessive training and how it can be detrimental to fertility and general health. The first risk factor is amenorrhea, a change in frequency or intensity of ones cycle over a short period of time. This is brought about by the shortening of the luteal phase by an increase in exercise. A more sever condition would be secondary amenorrhea which introduces low body fat percentage and body weight, high levels of exercise training, a drop in energy levels and possibly psychological stress. This could lead to what is known as the female triad, at this point demineralization of bones occurs due to the prolonged state of hypoesteogenia which distresses the equilibrium between bone reabsorption and bone remodelling (Dawson & Reilly, 2009; Harber, 2011).

It would be interesting to note the change experienced in breast pain throughout the menstrual cycle, more research is need in this area and will not be discussed in the scope of this study.

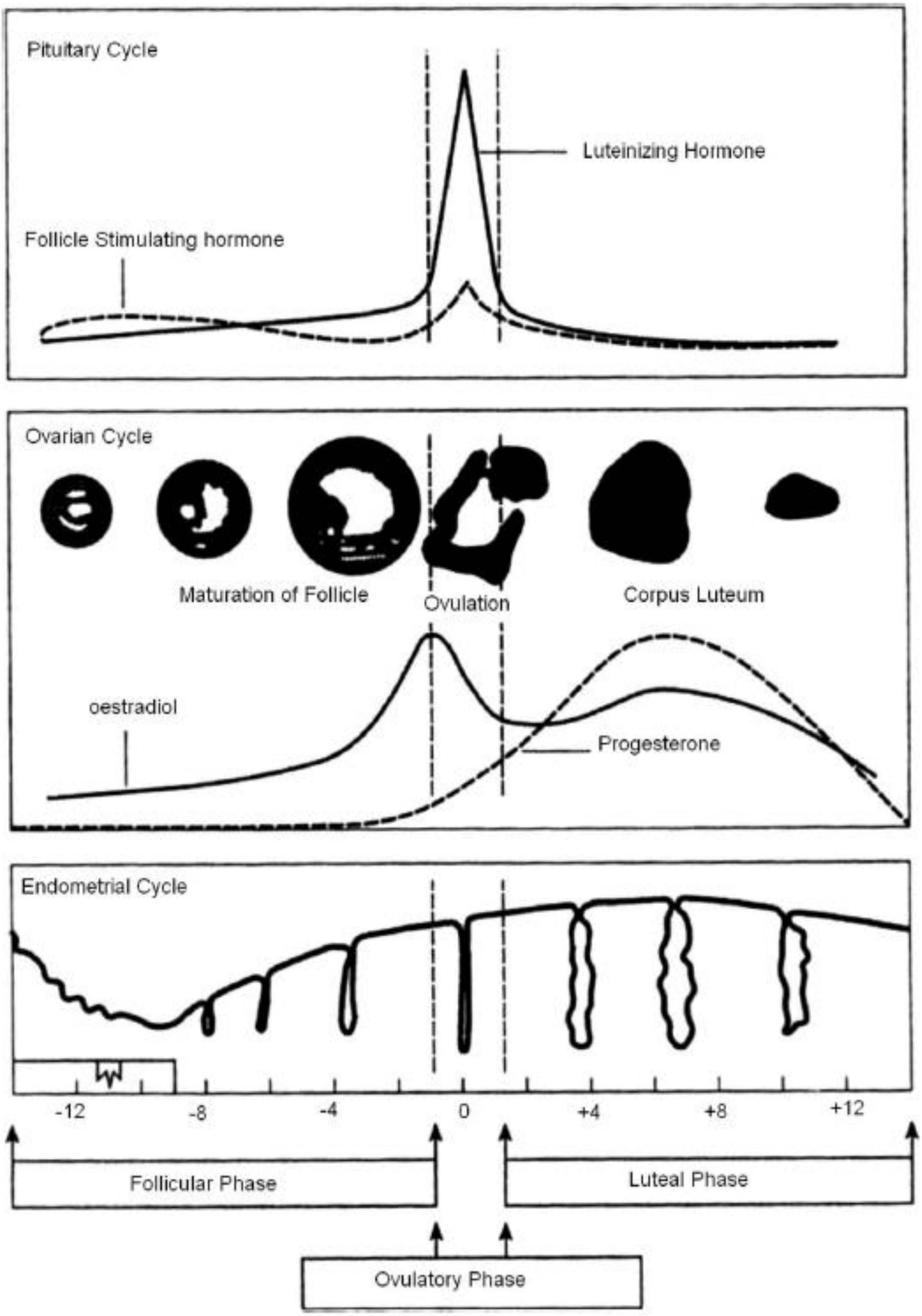
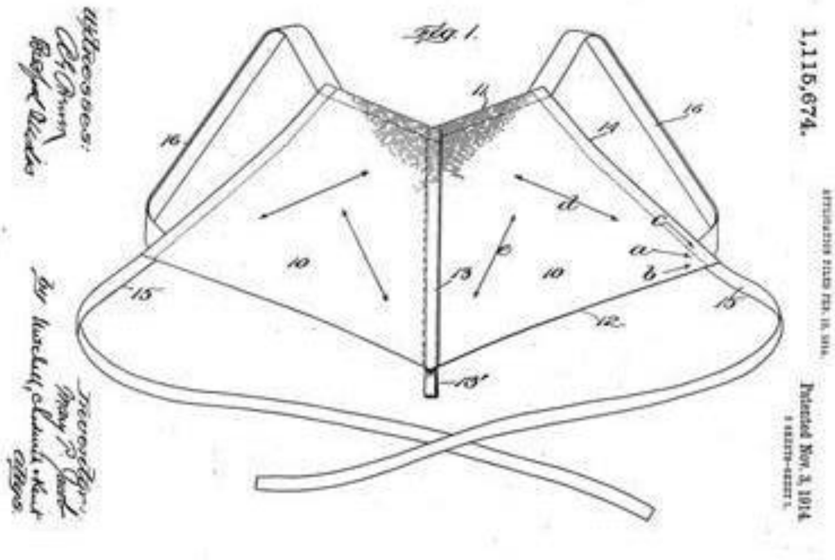


Figure 2.10: Changes in hormones, the ovary and the endometrium throughout a normal menstrual cycle (Dawson & Reilly, 2009).

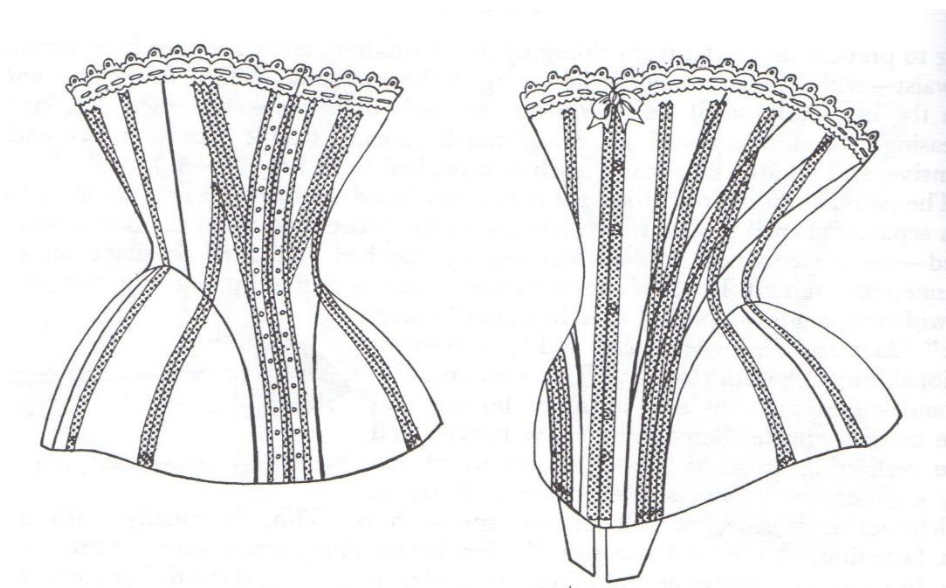
2.2 HISTORY OF THE BRASSIERE

The wearing of specialized garments to support the woman's breasts may possibly date back to ancient Greece. Women wore an apodesmos which translates to 'breast-band', this was a band of wool or linen that women used to wrap across their breasts and fastened at the back. Years later in the early 1900's women wore corsets to support the breasts. However corsets were moving down the trunk with fashion and no longer supported the breast at all. At this time a women by the name of Mary Phelps Jacob (Figure 2.11) designed the first 'bra' by using two hanky chiefs and a pink ribbon (Figure 2.12); this was a deviation from the whale bone corset (Figure 2.13). In 1914 Mary was offered $1500 from the New York Patent office to patent the new bra design (Page & Steele, 1999). In 1923 a women by the name of Essye K. Pollack started experimenting with different bust darts sewn into the fabric to flatter the bust by pinching the center front to uplift and contour the breasts (Figure 2.14). Soon this moved to individualized cups patented by Elvira Campa McKeefrey in 1926 (Wood, 2010).

Figure 2.11: Mary Phelps Jacob, inventor of the first bra (Aloke, 2011).



<u>Figure 2.12</u>: An illustration showing the first bra design by Mary Phelps Jacob, 1914 (Aloke, 2011).



<u>Figure 2.13</u>: ‘S’ shaped corset from 1900’s (Petersson, 2014).

At the start of the 1930's development of nylon and lastex (yarn that has an elastic core wound around with cotton, silk, nylon or rayon threads) further improved the fit and style of the bra which most resembles what we wear today. In 1937 because of these advancements individual cup sizes and band sizes of the bra was introduced (Wood, 2010).

In 1977 the first sports bra made its debut as two American female runners sewed two jock straps together to the inside of their t-shirts. Since then many researchers and developers have actively become involved in the development of better breast support during exercise using interdisciplinary elements such as ergonomics, dynamics, biomechanics, computer science and aesthetic science (Page & Steele, 1999; Li-xia *et al.*, 2009; Bowles *et al.*, 2011).

Figure 2.14: Bandeau-style bra 1920's (Wood, 2010).

Most modern designs focus on solving the fitness and comfort problems by improving the structure of the sports bra to act as a second skin offering enough support to the breast as well as comfort. The first of its kind the "Cool Guard" developed by the Massey University was composed of removable plastic cups made from a material known as polyethylene which is both flexible and lightweight. Following the "Cool Guard" was the Turtle Shell protective sports bra, the protective inserts were made of low density polyethylene plastic with ventilation holes, this design offered both protection to the breast during high impact sports as well as allowing for the transfer of moisture and evaporation; allowing the athlete to keep dry and comfortable. Both the "Cool Guard" and the Turtle Shell protective sports bra were functional insert cushion designs (Figure 2.15) (Li-xia *et al.,* 2009).

<u>Figure 2.15:</u> "Cool Guard" sports bra design and Turtle shell protective sports bra (Lia-xia *et al.,* 2009).

Certain bio-form wire was then introduced into bra design using sophisticated computer modeling software. The brassier wire often draws attention as the backbone variable and key element of the brassier as it fits the bony thorax, however it is one of the major sources of discomfort for the wearer (Lee & Hong, 2007). Due to the low cost of manufacturing the wire and its role in supporting the breast mass, many bra designs still incorporate it into the structure and support of the bra (Lee & Hong, 2007). Consequently computer engineers used dynamic non-linear finite element techniques to analyze the structural performance of the bra, straps and cups. These results showed fluctuating stress patterns on the breast during different gait patterns and a constant higher stress around the band of the bra (Li-xia *et al.*, 2009). Today there are many different sports bras to choose from the two most popular design are: Firstly, the encapsulating bra (Figure 2.16 (A)). The encapsulating bra is said to offer more support for women who are bigger busted with a cup size of C to D and require more support (Wood, White, Milligan, Ayres, Hedger, & Scurr, 2012). This design contains moulded cups that separate and support the breasts individually (Page & Steele, 1999; Scurr, White & Hedger, 2011). Second, the compression bra (Figure 2.16 (B)). is better suited for smaller busted women with a cup size of A to B. This bra type restricts the movement of the breast by compressing or flattening the breast tissue against the body (Figure 2.15).

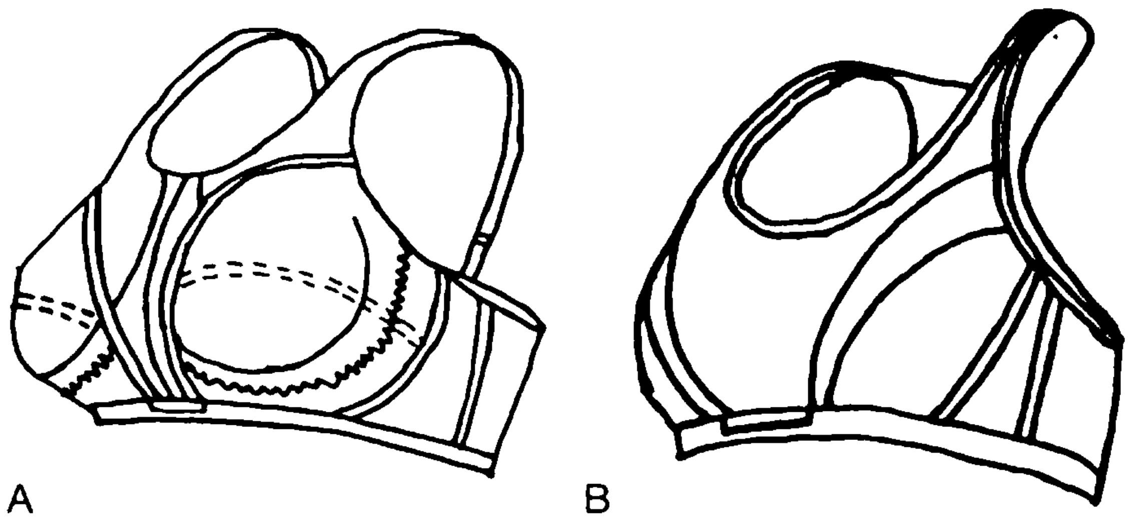


Figure 2.16: (A) Encapsulating bra. (B) Compression bra (Scurr *et al.*, 2011).

The new era of bra design also introduced the bra sizing system that incorporated cup size and around the bust measurements. It is important to remember in the sizing system that a B-sized cup is not the same for all around the bust measurements. That is to say cup size is relative to around the bust measurement (Page & Steele, 1999; Wood *et al.*, 2012).

Current research has moved to investigate strap support and comfort provided by sports bras. Consequently it has been reported that 41% of women choose not to wear a sports bra when participating in physical activity as the strap it uncomfortable and ill fitting. More importantly are reported cases of inappropriate bras shoulder strap fit and design which cause negative health impacts such as nerve damage of the neurovascular bundle and keloid scarring of the skin directly beneath the strap as a result of excessive downward pressure of the bra strap onto the clavicle narrowing the costoclavicular space (Campbell, Munro, Wallace & Steele, 2007; Bowles & Steele, 2013; McGhee, 2013). Although the purpose of the bra strap is not to support the breast in any way, larger busted women have been made known to tighten their bra straps in an attempt to bring the breast tissue up to the anterior chest wall. This in turn leads to majority of the weight of the breast tissue to be borne by the bra shoulder straps exerting high pressure on the shoulders of the wearer (Bowles & Steele, 2013).

Traditionally bra straps where designed to span the shoulders and attach to the girdle of the bra directly in line with the nipple. This was to prevent the straps from slipping off the shoulder and is shown to effectively decrease vertical displacement as the strap is directly aligned with the force vector generated by breast displacement while running. More recent strap designs include the racer-back, cross-back and T-bar designs (Figure 2.17) (Bowles & Steele, 2013). Biomechanical testing however has since shown that the cross-backed strap design is more effective that the traditional strap design in limiting breast displacement. The cross-back strap design traverse over the upper trapezius muscle on the posterior aspect of the shoulder, subsequently allowing better contact of strap cushioning on the flat muscle belly in a more level position than when compared to the traditional strap which passes over the bony spine of the scapula and as such the orientation of the cross-back strap results in a significant reduction in pressure experienced by the shoulder (Bowles & Steele, 2013). Researchers have since suggested that sports bras should be considered and essential piece of sporting equipment and not just a piece of underwear (Bowles & Steele, 2013).

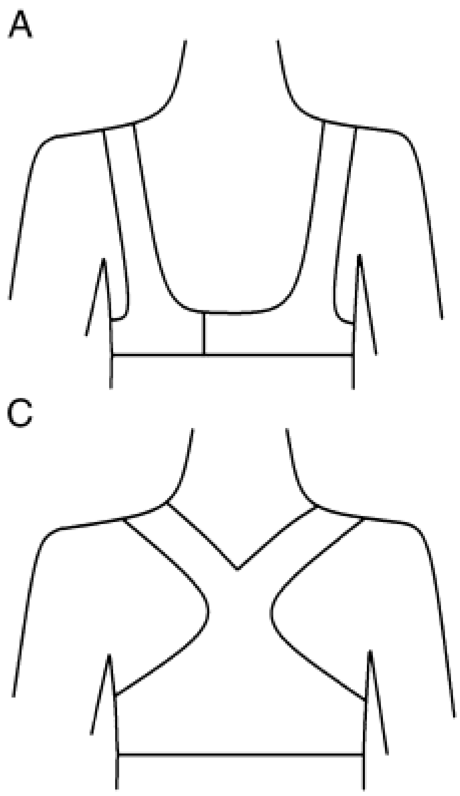


Figure 2.17: Sports bra shoulder strap orientation: Traditional shoulder strap (a); Cross-back shoulder strap (b); Racer-back (c); and T-bar shoulder strap (d) (Bowles & Steele, 2013).

2.3 IMPORTANCE OF BREAST SUPPORT

Physical activity has been associated with a number of negative consequences linked to a lack of appropriate support of the breasts (Scurr *et al*., 2010). Previous research has shown that up to 72% of exercising females experience exercise-related breast pain (Gehlsen & Albohm, 1980; Brown, White, Brasher & Scurr, 2014). This is believed to be the result of an increased amount of tensile forces acting on both the skin and fascia of the breast during movement. Repeated loading from physical activity also results in stretching of the supporting structures of the breasts (Page & Steele, 1999; Mason *et al*., 1999; Scurr, White, Milligan, Risius & Hedger, 2011) It has been proposed that the Cooper's ligaments act to give structural integrity to the breast and a loss in tension to these ligaments over time will result in sagging of the breasts (Page & Steele, 1999; Haake & Scurr, 2010). Matousek, Corlett & Ashton (2014) state that the pectoralis fascia also contributes to the integrity and anatomical structure and support of the breasts suspensory ligaments. The ligaments as well as nerves and vasculature pass through the retromammary space and attach onto the pectoralis major muscle (Scurr, Bridgman

& Hedger, 2010). It has also been suggested that the breast parenchyma or glandular tissue can accompany these tissues to the pectoralis muscle. This is important as we consider the anatomical connection between the breast tissue and the pectoralis major muscle as there is a reported increase in pectoralis major activation with lower levels of breast support. This may be indicative of a protective response by the body to reduce the tension experienced by the breast tissue and potential damage (Hamdi, Würinger, Schlenz & Kuzbari, 2005).

Complaints of muscular pain experienced in the neck, shoulders and back are also common particularly in larger busted women and contribute to negative health outcomes, and may discourage females from participating in physical activity (McGhee, Steele & Power, 2007; McGhee, Steele, Zealey & Takacs, 2013).

These factors can be so dire that large busted women feel the need to pursue reduction mammoplasty along with a reduction in sports participation (McGhee, 2013; Milligan, 2014). Reducing sports participation may propagate the reoccurrence of the pain such as neck and back ache due to the decrease in energy expenditure and physical activity which can lead to weight gain and in turn lead to an increase in breast mass (Wood, Cameron, & Fitzgerald, 2008; McGhee, 2013). The consideration of bra design is important as the bra acts as an external source of breast support. Although research has shown that sports bras are more effective than fashion bras in reducing breast displacement and mastalgia only 41% of women choose to wear a sports bra during physical activity (Bowles & Steele, 2013; McGhee, 2013).

It is important to note that breast pain or mastalgia can be dived into non-cyclic and cyclic mastalgia. Non-cyclic mastalgia is defined as a constant or intermittent pain that is not related to the menstrual cycle. Cyclic mastalgia is most prominent toward the end of the menstrual cycle and is thought to have a hormonal aetiology. A variety of treatment modalities are provided including pharmacological treatment which can provide temporary relief, and correct nutrition and wearing a well fitted sports bra (Brown *et al*., 2014). Wearing a well fitted sports bra has shown to decrease the effects and symptoms of 85% of women who wear them in both cyclic and non-cyclic mastalgia with no associated side effects (Brown *et al*., 2014).

In order to understand exercise-related breast pain and quantify breast motion, research has linked improvements in breast comfort with a reduction in vertical breast displacement and vertical breast velocity (Haake & Scurr, 2010). The configuration of the breast is composed of connective tissues collagen and elastin; while surrounding tissue of the mammary glands and other structures involved in lactation is composed of adipose tissue (Haake & Scurr, 2010). The breast is assumed to be symmetrical, and as such that dynamic displacements above and below the static equilibrium are equal. The motion cycle of the breast as a whole is represented by the nipple while the motion of the upper body is represented by the suprasternal notch (Haake & Scurr, 2010). As manufacturing companies are moving towards the manufacturing of activity-specific breast support (e.g. running bras) it is beneficial to know the movement of the breast during the gait cycle (Scurr *et al*., 2010).

A sinusoidal pattern has been used to describe the movement of the breast tissue and the trunk with treadmill running, with a time delay between the movement of the trunk and the movement of the breast (Haake & Scurr, 2010; McGhee, 2013). This can be explained by examining ones gait cycle. In the gait pattern as heel strike occurs the lowest point of downward vertical trunk displacement is reached, the trunk has stopped moving vertically downward as the heel strikes and begins to ascend. The lowest downward point of vertical displacement of the breast occurs shortly after and causes the breast tissue to strike against the anterior thorax as the breast tissue is still on its decent and the trunk on its ascent (Haake & Scurr, 2010; McGhee, 2013). The jarring effect of this movement by the trunk and the breast tissue in relation to the net forces being experienced has been associated with exercise-induced breast pain (McGhee, 2013). The net forces accompanying breast displacement during physical activity include the driving force of the trunk, restrained by stiffening and dampening forces by anatomical restraint of the breast and bra, as well as gravity. Anatomical restraints include the Cooper's ligaments connecting the breast tissue to the pectoral fascia via thin fibrous bands of tissue within the breast along with the overlying skin.

Quantifying these forces can help assist in explaining the clinical phenomena of poor posture and musculoskeletal dysfunctions in the upper torso experienced by women with a larger bust as a result of the weight of the breast acting anterior to the trunk. It could also help explain why some bras cause upper limb nerve dysfunction and ill-fitting straps which leave furrows in the shoulders (Wood *et al.,* 2008; Bowles & Steele, 2013; McGhee, 2013). Changes in static spinal posture have also been researched and suggest that women with larger breasts may experience increased cervical lordosis and thoracic kyphosis as the center of gravity is shifted away from the spine and recruitment of musculature is need to support and maintain balance (Wood *et al.*, 2008). It is important for women to be informed that the correct breast support therefore is not only necessary for limiting breast displacement and discomfort but also to limit breast force generation and secondary musculoskeletal dysfunctions which may follow (McGhee, 2013).

Past research has measured these movements, firstly bare-breasted followed with a sports bra and in some research with a commercial t-shirt bra, using video analysis. Retro-reflective markers are placed on the right and left nipples, suprasternal notch, and the anteroinferior aspects of the 10th ribs. During the bra conditions markers were repositioned on the bra over the nipple (Scurr *et al*., 2010). Collected data includes; breast size, breast mass, running speed and bra type, as well as movement of the breast in three-dimensional (3D) space. This is described as six degrees of freedom: namely the ability of the breast to move in three directions anteriorly/posteriorly, superiorly/inferiorly, medially and laterally (White *et al.*, 2009; Zhou *et al*., 2012*)*.

Current research in bra design is moving toward the reduction of medial/lateral displacement to improve performance. White and colleagues (White *et al.*, 2009) found that decreasing levels of breast support resulted in medial ground reaction force being increased. This increase was attributed to an increase in mediolateral breast displacement generating a greater amount of torque about the vertical axis of the trunk. A "comfort scale" designed by Heil's (1993) is beneficial, and designed to measure personal comfort and perceived pain (Mason *et al.*, 1999).

Electromyography (EMG) is another method that has be used to measure and try understand how the associated muscle groups of the upper quarter involved in running and around the breast influence mastalgia and breast displacement (Milligan, Mills & Scurr, 2014). A reduction in muscle activity leads to a reduction in energy cost which is beneficial to female runners. Research however is still needed in this field to establish whether additional mass and independent soft tissue movement affects the magnitude of myoelectrical activation and motor unit recruitment of the muscles in the upper body namely, pectoralis major, anterior and posterior deltoids and the trapezius (Milligan, 2014).

It has been established that in bigger busted women with a minimum cup size of D compared to smaller sup sizes, experience more muscle activation measured with the EMG. Small movements involving postural tasks illicit an increase in muscle tension due to the increased breast mass. Milligan (2014) concluded that this is indicative of the involvement of certain muscles contributing to mastalgia as there would be an increase in muscle tension with activities such as running. However with the correct breast support mastalgia experienced as a result of muscle activation and tension from external forces or gravity can be reduced and controlled (Milligan, 2014).

Unfortunately motion in the breast is difficult to reduce as there are no strong intrinsic structural supports in the breast. Research has shown as mentioned previously that the Cooper's ligaments are the primary supporting structures in the breast with the skin as a secondary support. Therefore sports bras are designed specifically to provide a firm support for the breasts during exercise, and undertake the function of protecting the breasts against sporting injuries (Page & Steele, 1999; Li-xia *et al.*, 2009). This is accomplished via the bras ability to control the movement in both horizontal and vertical directions, which is the fundamental cause of pain and discomfort associated with exercise (Li-xia *et al.*, 2009; White *et al.*, 2009). A study done by Haake *et al* (2011) shows that fitting the correct bra is better aided in relieving cyclic-mastalgia as well as non-cyclic-mastalgia with no side effects than with taking drugs. Many studies have been done that look at the mechanics of the skin and ligaments. We can apply this to the breast tissue as well. Haake *et al* (2011) state that there are three phases of the force extension curves of the skin: 1.) the initial extension phases comprised of stretching the collagen fibers. 2.) The extension of the collagen fibers known as the stiffening extension phases. 3.) The failure phase as individual fibers break. For the skin the strain is experienced at 40-80% here after failure occurs at 100% strain.

Majority of breast biomechanics is centered on treadmill running and fails to report on optimum breast support parameters with alternative activities and breast displacement when performing such activities (Risius, Milligan, Mills & Scurr 2015). Until breast displacement is understood in different activities the support requirements of the breast are unknown. By determining the multiplanar breast support requirements through the understanding of direction and magnitude of bare-breast displacement, acceleration and velocity may improve bra design (Scurr *et al*., 2010). Literature has suggested that a single bra design may not be appropriate for all optimal support for all activities (Risius *et al*., 2015). Breast support requirements may be influenced by the direction of breast tissue displacement along with breast mass. Agility test and jumping are examples of sporting movements that may aid in the assessment of breast displacement in a multiplanar view (Risius *et al*., 2015). Bridgeman *et al.*, 2010 reported that star jumping (Figure 2.14) elicited a 58% displacement of breast tissue in the vertical plane while running elicited a 26-50% displacement of the breast tissue. Risius *et al*., 2015, suggested that exercise modalities that require jumping and agility require significantly more support in the vertical and mediolateral plane than with just running (Scurr *et al*., 2010).

There are two phases in the movement performed for the Two-Step Star Jump test (Figure 2.18). Phase one is comprised of the upward stage where lower limbs push off the ground and arms are abducted away from the body, breasts are displaced in the X, Y and Z-Planes. In the downward stage breast displacement is medial and downward as lower limbs make contact with the ground (Bridgman *et al*., 2010). Phase two showed displacement of breast tissue medially (X-plane) and vertically (Z-plane) as upper and lower limbs are adducted, with the downward phase breast tissue was displaced posteriorly (Y-Plane). Previous research has established that with the Two-Step Star Jump test more displacement of breast tissue is experienced in the vertical (Z) plane. Comparisons of displacement with different breast supports while performing a Two-Step Star Jump test have not been conducted in previous studies.

This highlights the importance of further investigating the percentage distribution of breast displacement, velocity and acceleration. It is necessary for sports bras to possess an array of mechanical properties if they are to be used in multiple sporting activities (Risius *et al*., 2015). A combination of elasticity and stiffness is required. Elastic material needs to allow for upper body movement and natural breathing while stiffness is required for the support of the breast tissue to discourage displacement (Page & Steele, 1999; Risius *et al*., 2015).

<u>Figure 2.18</u>: Two-Step Star Jump test (Bridgman *et al*., 2010).

As breast movement and pain may discourage exercise, the use of the appropriate sports bra may enhance performance and enjoyment in sport or activity (Mason *et al.*, 1999).

Two major designs aim to limit the internal forces within the breasts, and reduce exercise associated pain and discomfort: (i) encapsulating bra; and (ii) the compression bra. For females that require more support encapsulating bras seem to be more effective as each breast is supported separately by a moulded cup. Compression bras are designed to restrict movement by compressing or flattening the breasts against the body to reduce the force momentum of the breast mass to the thorax (Page & Steele, 1999; Zhou *et al*., 2012).

It is essential that women wear the appropriate bra for support during activity. Adequate support may prevent the negative implications of sport participation such as breast pain, irreversible breast sag and a decrease in sports participation (Mason *et al.*, 1999; Page & Steele, 1999; White *et al.*, 2009).

2.3.1 DETERMINING THE CORRECT BRA FIT

An ill-fitting bra can become a medical issue contributing to negative health outcomes as discussed previously such as upper limb neural symptoms and deep bra furrows created by excessive strap pressure (McGhee & Steele, 2010). Research suggests that majority of women where the incorrect fitting bra (Wood *et al.*, 2008; McGhee & Steele, 2010). Women can use the following guidelines to determine the correct fit for themselves if they are unable to see a professional. First one must look at the band of the bra; does it fit to tight that the flesh bulges over the top of the band leading to feelings of discomfort, or is it a loose fit that results in the band moving up when arms are raised above the head. This would consequently display a rise in the posterior band above the inframammary fold. The front band needs to be in full contact and flush with the sternum (Wood *et al.*, 2008; McGhee & Steele, 2010). Second the cup size; are there wrinkles in the fabric, this would indicate the cup being too big. If the cup were to be too small breast tissue would bulge above, below or at the sides of the cup. Incorrect shape of the underwire results in the underwire pressing on the breast tissue laterally (under the armpit) (McGhee & Steele, 2010). Succeeding these criteria the straps should be observed. To tight and the strap will dig into the shoulder, carrying too much weight of the breast and not distributing the load throughout the bra. If the straps are too loose they will slide off the shoulder and not be adjustable. The bra is a correct fit if there are no errors in the above criteria or if they can be adjusted to allow for the correct fit (McGhee & Steele, 2010).

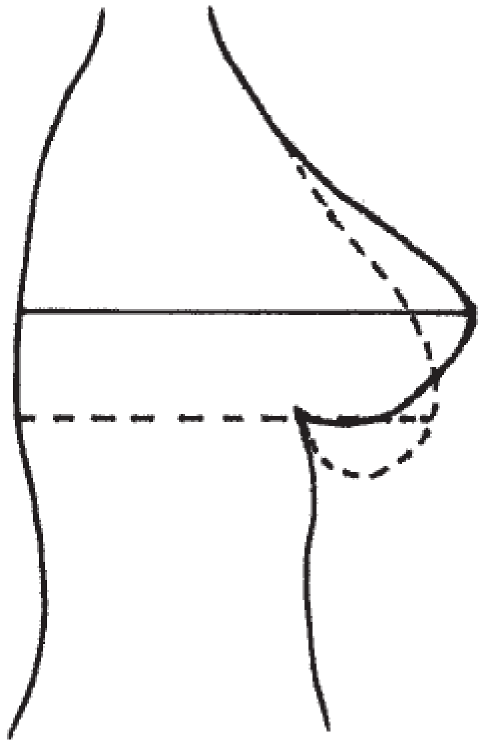


Figure 2.19: Bra size calculation from under bust and over bust circumference (McGhee & Steele, 2006).

Additional measurement that can be done at home are over the bust and under the bust measurement (Figure 2.19). Over the bust measurement indicated by the solid line in Figure 2.15 is taken at the most prominent point of the breast tissue with the tape measure level at the back and not pressing into the tissue. This should be done standing and braless so that the breast tissue is independent (McGhee & Steele, 2006; Wood *et al.,* 2008). The second measurement shown by the dotted line in Figure 2.18 is the under bust measurement at the inframammary fold. Subject should stand braless and support the breast tissue to expose the inframammary fold for measurement (McGhee & Steele, 2006). These two measurements can then be used to calculate band size and cup size of the correct fitting bra for the individual. A standard number of four inches is added to an even value under bust measurement while a standard number of five inches is added to an uneven value under bust measurement. This will give the band size in inches that should be worn e.g. 32 inch band size (McGhee & Steele, 2006; Wood *et al.,* 2008). Cup size is calculated by the difference in over bust circumference and calculated band size. For every inch of difference there is an increase of one cup size (McGhee & Steele, 2006).

It is valuable to go through both the selection criteria and measurements when selecting a bra as using only the measurements may not always be sufficient as bra manufactures lack of consistency with respect to band length and cup volume (McGhee & Steele, 2006).

CHAPTER THREE: METHODS & PROCEDURES

3.1 METHODS

In this chapter the methods and procedures used for the testing of participants will be discussed.

3.1.1PARTICIPANTS

Before commencement of the study ethical clearance for this study was obtained from the Postgraduate and Ethics Committee of the Faculty of Humanities, University of Pretoria, South Africa (Appendix F). A group of 17 female participants were included in the study. Participation was voluntary and all participants completed and signed a consent form prior to participation in the study.

Criteria used to determine the eligibility of a subject, for the study, was as follows:

- INCLUSION CRITERIA
  - Female participants aged between 17-39 years,
  - Cup size of B-C, (Table 3.1)
  - Familiar with treadmill running,
  - Participate in at least 30 minutes of exercise twice per week.

- EXCLUSION CRITERIA
  - Females that have under gone any surgical procedures to the breasts
  - Pregnant within the last year

Table 3.1: Participants bra size

Bra Size	Frequency	Percentage
32C	**1**	**5.9**
34B	**10**	**58.8**
34C	**3**	**17.6**
36B	**1**	**5.9**
38C	**2**	**11.8**
Total	**17**	**100.0**

3.1.2 SETTING

Testing took place in a controlled environment at Ergonomics Technologies laboratories in Centurion and the Institute for Sports Research (ISR). Only three female researchers were present in a private room with one participant at a time due to the sensitive nature of the study. Eight cameras were set up around the treadmill.

3.1.3 EQUIPMENT

EQUIPMENT USED	
Stature (standing)	Seca Athropometer
Body Mass	Seca Scale
Breast size measurements	Steel anthropometric measuring tape
Running test	Technogym Treadmill
Video analysis	Qualisys motion capture hardware and Software. Retro-reflective markers

3.2 PROCEDURES

Each participant was assessed on three separate occasions.

1) Stature, body mass and breast measurement.
2) Three randomly selected treadmill and Two-Step Star Jump conditions.
3) Three randomly selected treadmill and Two-Step Star Jump conditions.

3.2.1 MEASURMENTS

Participants were tested on three separate occasions with one day rest between each:

1. Body mass, stature and breast size measurement.
2. Incremental treadmill and Two-Step Star Jump test (3 conditions).
3. Incremental treadmill and Two-Step Star Jump test (3 other conditions).

Testing took take place over a period of 5 days to accommodate all participants.

- Test day 1: Body mass, stature and breast size measurement.
- Test day 2: Body mass, stature and breast size catch-up as well as incremental treadmill tests.
- Test day 3: Incremental treadmill and Two-Step Star Jump test.
- Test day 4: Incremental treadmill and Two-Step Star Jump test.
- Test day 5: Incremental treadmill and two- Two-Step Star Jump test.

Treadmill and Two-Step Star Jump tests were completed by the participants in six randomly ordered bra conditions.

Measurements included:

- Anthropometric measurements (body mass, stature and breast size measurements, following the recommendation of McGhee and Steele (2006).
- Motion capture analysis focusing on breast movement during an incremental treadmill and Two-Step Star Jump test.
- Subjective questionnaire to determine breast comfort during the various conditions.

Breast size measurement:

Breast size measurement was taken following the recommendation of McGhee and Steele (2006). A qualified anthropometrist (International Society for the Advancement of Kinathropometry – ISAK) measured the participant's bra size using a steel anthropometric measuring tape. Measurements were taken while participants stood braless with arms relaxed at the side. Following expiration under-bust chest circumference to determine chest girth was measured level with the inframammary fold followed by over-bust chest circumference, measured at the most prominent part of the breast to determine cup size (McGhee & Steele, 2006). Band size is then calculated using the standard method of bra size estimation. An arbitrary number of four inches is added to an even under bust measurement and five inches to an odd under bust measurement. For example an under bust measurement of twenty-eight inches resulted in a thirty-two inch band. Cup size is then calculated based on the difference between the over bust measurement and the calculated band size. For example an over bust measurement and band size difference of one inch equated to an A cup, whereas two inches differences equated to a B cup (McGhee & Steele, 2006).

Figure 3.1 High Impact Ultimate Shock Absorber Bra

Figure 3.2 High Impact Aerobics Bra

Figure 3.3 Medium Impact Bra

Figure 3.4 Low/Light Impact Bra

Motion capture analysis (breast movement):

The Qualisys Motion Capture Analysis hardware and software was used for the biomechanical evaluation (Figure 3.5). Retro-reflective markers were placed on the right nipple, suprasternal notch, and the anteroinferior aspects of the 10th ribs (Figure 3.6). During the bra conditions markers were repositioned on the bra over the nipple (Scurr *et al*., 2010). The retro-reflective markers are used as reference points to determine breast displacement and the percentage of breast displacement reduction. Participants completed the standard incremental treadmill test. Starting with a two minute familiarization period at 4km/h, breast displacement was recorded during five strides. Speed was then steadily increased by 1km/h over two minutes, breast displacement was recorded during a further five strides. Increments in speed and breast displacement measurements were continually taken until the participant reached their maximum running speed on the treadmill or until requested to stop the test (Scurr *et al*., 2010). Participants were given a two minute resting period after which they performed an additional five repetitions of the Two-Step Star Jump during which breast displacement was recorded. The Two-Step Star Jump consists of two phases. The first phase begins with the participant feet shoulder width apart, followed by lateral jump, abducting both the arms and the legs until ground contact.

Phase two is comprised of the participant jumping medially, adducting both the feet returning to the starting position (Bridgman *et al*., 2010). Research has suggested that performing Two-Step Star Jump test is a valuable test or movement to analyse with regards to breast displacement, as it is a dynamic whole body movement (Stamford, 1996). This test requires motor coordination between upper and lower-body segments and includes both horizontal and vertical movements (Bridgman *et al*., 2010).

After each condition participants rated their overall breast comfort using the visual analog scale for breast comfort developed by Hell's (1993) and presented by Mason *et al* (1999). Participants assessed bra comfort, perceived support, fit, likes and dislikes. The treadmill test was then repeated in the next bra condition after participants had adequately recovered.

Figure 3.5: Laboratory set-up for each testing session; treadmill positioned centrally with eight cameras positioned around the treadmill.

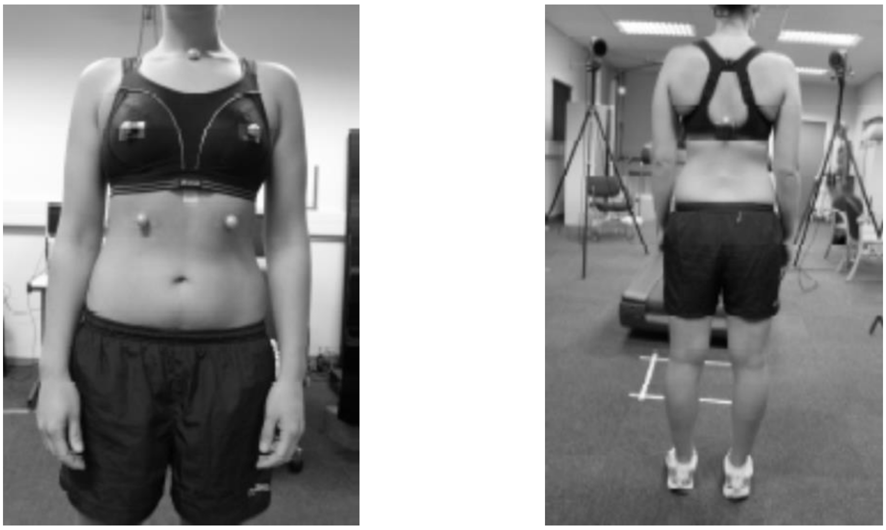


Figure 3.6: Positioning marker for biomechanical assessment

3.4 RESEARCH DESIGN

This study was a cross-sectional experimental study. Four different sets of data were analysed. 1) Displacement of the Right Breast (RB) in the X (mediolateral displacement of the breast), Y (anteroposterior displacement of the breast) and Z (vertical or superorinferior displacement of the breast) planes. 2) Percent reduction of RB displacement in each plane of movement X, Y, Z in relation to the Control (no bra condition). 3) Percent reduction of RB displacement in each plane of movement X,Y,Z with the HIU bra compared to the Control, participants Own bra and remaining three shock absorber bras of varying levels of support (Figure 3.1, 3.2, 3.3, 3.4) . 4) Residual displacement (overall displacement), and percent reduction with the HIU bra compared to the Control, participants Own bra and remaining three shock absorber bras of varying levels of support.

Tests for normality were performed to determine data distribution and therefore whether parametric or non-parametric statistical analyses should be used; these included the Kolmogorov-Smirnov and Shapiro-Wilk tests. As a result of the atypical data distribution non-parametric statistical analyses were selected for further analysis of the data and included the Wilcoxon signed ranks test and the Friedman test.

3.5 STATISTICAL ANAYLSIS

Statistical analysis was performed using SPSS statistics package 4.0. Data is presented as means ± standard deviation and significance is set at $p<0.05$. Non-parametric statistics were used for the analysis. Differences across the breast support conditions were assessed using the Friedman test and repeated Wilcoxon signed-rank test. The Friedman test is an extension of the Wilcoxon test and assumes all observations are mutually independent, results in one row do not affect the results in another row, thus rows are mutually independent, and data can be meaningfully ranked. If the test gives a significant result the Wilcoxon signed-ranks test will be used to make pairwise comparisons. Data are paired and the difference comes from the same population, each pair is chosen randomly and independently. Data need not be normally distributed but should be symmetric around the median (Von Ossiezky, 2013).

Difference in peak vertical, mediolateral and anterior posterior kinematics of the breast were assessed using the Kruskal-Wallis test and multiple Mann-Whitney U-test. A relationship between peak breast kinematic values and breast comfort was also established and averaged across the gait cycle.

Mann-Whitney U-Test assumptions include that samples are independent of each other, data is not normally distributed but each sample should have the same shape. The Kruskal-Wallis test was used as an extension of the Mann-Whitney U-test. This allows the identification of a significant difference when at least one sample is different from the other samples. Assumptions for this test are that there is mutual independence between samples, observations within a sample are independent, the data need not be normally distributed, but the distribution of the samples should be the same (Von Ossiezky, 2013).

CHAPTER FOUR: RESULTS & DISCUSSION

4.1 INTRODUCTION

Descriptive statistics were used to calculate the minimum, maximum and mean displacement in millimetres (mm) of the breasts while running on the treadmill at 4, 6, 8, and 10 km/h respectively.

4.2 Treadmill Running:

4.2.1.1 Lateral (X) displacement of the breast:

Lateral breast displacement at 4km/h

Lateral displacement of the breast at 4km/h was found to have the least amount of displacement while participants were wearing their Own bra (4.78mm). The same trend was noted for maximal mediolateral displacement while the participants were wearing their Own bra (80.68mm). The Low level support bra had the lowest mean lateral breast displacement in relation to the other bras showing that the best support was experienced while wearing the Low level support bra with a median of (13.9mm) see Table 4.1. The median was used for further interpretation of the data instead if the mean and will be discussed below. This is as a result of asymmetrical data distribution.

4.2.1.2 Anteroposterior (Y) displacement of the breast:

Anteroposterior displacement of the breast at 4km/h

Anteroposterior displacement of the breast at 4km/h was found to have the least amount of displacement while participants were wearing the Medium impact level support bra (6.3mm); with a maximum displacement while wearing their own bra (72.2mm). Looking at the mean for anteroposterior displacement at 4km/h shows that the best support was experienced while wearing the Low impact level support bra with a median of (13.6mm) see Table 4.1.

4.2.1.3Superior inferior (Z) displacement of the breast:

Superior inferior displacement of the breast at 4km/h

Superior inferior displacement in the breast at 4km/h was found to have the least amount of displacement while participants were wearing the Medium impact support level bra as well as when wearing the HIU bra (5.6mm); with a maximum displacement with the no bra Control (48.1mm). Looking at the median for superior inferior displacement at 4km/h shows that the best support was experienced while wearing the Medium impact level support bra with a median of (13.8mm) see Table 4.1.

4.2.1.4Residual displacement (overall breast displacement) of the breast

Residual displacement of the breast at 4km/h

Residual displacement in the breast at 4km/h was found to have the least amount of displacement while participants were wearing the HIU bra (4.47mm); with a maximum displacement with the no bra Control (45.85mm). Looking at the median for Residual displacement at 4km/h shows that the best support was experienced while wearing the Medium impact level support bra with a median of (15.26mm) see Table 4.1

Table 4.1 Breast displacement while running on the treadmill with six different support levels respectively at 4km/h in the X, Y, Z-Planes and Residual displacement.

X-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	14,60	71,87	29,92	16,26	23,22
RB x Displacement Own	17	4,78	80,68	29,02	20,88	20,22
RB x Displacement Low	17	9,00	19,12	13,90	3,30	13,64
RB x Displacement Med	17	7,28	29,43	18,01	5,14	19,16
RB x Displacement High	17	12,36	36,79	23,53	7,66	21,24
RB x Displacement HIU	17	9,33	40,95	21,99	9,14	18,65

Y-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	14,03	45,92	26,55	9,16	23,68
RB x Displacement Own	17	7,99	72,18	22,39	18,05	17,32
RB x Displacement Low	17	9,63	18,01	13,15	2,43	12,65
RB x Displacement Med	17	6,26	62,56	15,76	12,68	12,34
RB x Displacement High	17	9,25	47,15	20,26	9,34	19,25
RB x Displacement HIU	17	8,39	33,66	18,29	6,98	17,21

Z-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	10,59	48,11	20,36	11,31	16,23
RB x Displacement Own	17	7,69	36,08	18,13	7,91	17,49
RB x Displacement Low	17	8,98	41,84	20,20	10,34	16,93
RB x Displacement Med	17	5,59	37,02	13,82	7,39	12,37
RB x Displacement High	17	8,97	35,03	17,27	6,39	16,55
RB x Displacement HIU	17	5,59	35,69	17,22	8,35	14,91

Residual Displacement

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	10,63	45,85	21,86	13,12	15,94
RB x Displacement Own	17	9,98	33,09	18,31	7,42	15,88
RB x Displacement Low	17	13,56	25,61	20,61	3,51	21,02
RB x Displacement Med	17	9,86	33,09	15,85	5,15	15,26
RB x Displacement High	17	8,40	25,98	16,47	4,82	16,60
RB x Displacement HIU	17	4,47	25,37	15,26	5,75	16,27

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

The Friedman's Test was used to compare the medians and identify if there was any significant difference between the medians. It was found that in the X-Plane and Y-Plane that at least one bra (HIU bra, see below) performed differently with the significant difference of p=0.00 and p=0,001 respectively.

The Wilcoxon signed ranks test was then used to rank the data to calculate and identify which of the six bras showed a significant difference between the Control and the six support levels. This test compared samples without making assumptions about the underlying data distribution. For results to be of significant value the p-value must be equal to or less than 0.05 (p=0.05). A significant difference of p=0.002 was found between the HIU bra in comparison to the Low impact support bra at 4km/h. All other bras performed similarly in the X-Plane. In the Y-Plane a significant difference in performance was found in the Control compared with the HIU bra (p=0.019) and the HIU bra compared with the Low impact support bra (p=0.006). No significant difference was found in the Z-Plane or Residual displacement at 4km/h, see Table 4.2.

Table 4.2 Wilcoxon Signed-rank test data for breast displacement while running on the treadmill with six different support levels respectively at 4km/h in the X, Y, Z-planes and Residual displacement.

X-plane

Wilcoxon Signed-rank test

	RB x Displacement HIU - RB x Displacement Control	RB x Displacement HIU - RB x Displacement Own	RB x Displacement HIU - RB x Displacement Low	RB x Displacement HIU - RB x Displacement Med	RB x Displacement HIU - RB x Displacement High
Z	-1.538[b]	-.686[b]	-3.101[c]	-.828[c]	-.355[b]
Asymp. Sig. (2-tailed)	,124	,492	,002	,407	,723

Y-plane

Wilcoxon Signed-rank test

	RB y Displacement HIU - RB y Displacement Control	RB y Displacement HIU - RB y Displacement Own	RB y Displacement HIU - RB y Displacement Low	RB y Displacement HIU - RB y Displacement Med	RB y Displacement HIU - RB y Displacement High
Z	-2.343[b]	-.497[b]	-2.722[c]	-1.160[c]	-.592[b]
Asymp. Sig. (2-tailed)	,019	,619	,006	,246	,554

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior Posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

4.2.2.1 Lateral (X) displacement of the breast:

Lateral breast displacement at 6km/h

Lateral displacement of the breast at 6km/h was found to have the least amount of displacement while participants were wearing their Own bra (9.0mm). The same trend was noted for maximal displacement while the participants were wearing their Own bra (98.0mm). The HIU bra had the lowest mean lateral breast displacement in relation to the other bras, showing that the best support at 6km/h for lateral displacement was experienced while wearing the HIU bra with a median of (25.0mm) see Table 4.3.

4.2.2.2 Anteroposterior (Y) displacement of the breast:

Anteroposterior displacement of the breast at 6km/h

Anteroposterior displacement of the breast at 6km/h was found to have the least amount of displacement while participants were wearing their Own bra (9.0mm); with a maximum displacement while also wearing their Own bra (59.0mm). Looking at the median for anterior posterior displacement at 6km/h shows that the best support was experienced while wearing the Low impact level support bra with a median of (19.0mm) as well as while wearing the Medium impact support bra (19.0mm) see Table 4.3.

4.2.2.3Superior inferior (Z) displacement of the breast:

Superior inferior displacement of the breast at 6km/h

Superior inferior displacement in the breast at 6km/h was found to have the least amount of displacement while participants were wearing their Own bra (8.0mm) as well as in the Control with no bra (8.0mm); with a maximum displacement with the Medium impact support level bra (83.0mm). Looking at the median for superior inferior displacement at 6km/h shows that the best support was experienced while wearing the Low impact level support bra with a median of (20.0mm) as well as the HIU bra (20,0mm) see Table 4.3.

4.2.2.4 Residual displacement of the breast

Residual displacement of the breast at 6km/h

Residual displacement in the breast at 6km/h was found to have the least amount of displacement while participants were wearing their Own bra (7.0mm); with a maximum displacement with the Low impact support level bra (63.0mm). Looking at the median for Residual displacement at 6km/h shows that the best support was experienced while wearing the High impact level support bra with a median of (19.0mm) see Table 4.3.

Table 4.3 Breast displacement while running on the treadmill with six different support levels respectively at 6km/h in the X, Y, Z-planes and Residual displacement.

X-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	13	51	32,53	11,424	35,00
RB x Displacement Own	17	9	98	35,82	22,782	31,00
RB x Displacement Low	17	15	60	31,71	13,990	31,00
RB x Displacement Med	17	10	46	32,06	10,009	32,00
RB x Displacement High	17	20	44	31,47	6,947	33,00
RB x Displacement HIU	17	12	53	28,88	10,523	25,00

Y-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	19	50	28,94	9,384	25,00
RB x Displacement Own	17	10	51	27,71	14,260	21,00
RB x Displacement Low	17	9	59	22,29	12,849	19,00
RB x Displacement Med	17	12	37	21,41	7,690	19,00
RB x Displacement High	17	17	35	27,53	5,088	28,00
RB x Displacement HIU	17	13	55	26,12	9,578	24,00

Z-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	8	65	26,12	13,448	22,00
RB x Displacement Own	17	8	80	23,35	16,549	21,00
RB x Displacement Low	17	13	52	22,35	9,192	20,00
RB x Displacement Med	17	9	83	25,88	16,062	24,00
RB x Displacement High	17	12	55	23,88	9,144	24,00
RB x Displacement HIU	17	9	52	24,35	11,800	20,00

Residual Displacement

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	26	44	30,94	4,279	30,00
RB x Displacement Own	17	7	45	22,24	9,602	24,00
RB x Displacement Low	17	12	63	30,65	11,208	30,00
RB x Displacement Med	17	11	38	21,88	7,262	22,00
RB x Displacement High	17	12	52	21,65	8,972	19,00
RB x Displacement HIU	17	10	46	27,47	11,276	27,00

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

The Friedman's Test was used to compare the medians and identify if there was any difference between the medians. In the Y-Plane a significant difference of p=0.018 was found showing that at least one bra performed differently, as well as in Residual displacement with the significant difference p=0,001. No significant difference was found in any of the other planes.

To identify, rank and calculate which of the six bras showed a significant difference between the Control and the six support levels the Wilcoxon signed rank test was then used. This test compared samples without making assumptions about the underlying data distribution. For results to be of significant value the p-value must be equal to or less than 0.05 ($p \leq 0.05$). A significant difference of p=0.039 was found between the HIU bra in comparison to the High impact support bra at 6km/h for Residual displacement. All other bras performed similarly in the X-Plane, Y-Plane and Z-Plane with no significant difference found, see Table 4.4.

<u>Table 4.4</u> Wilcoxon Signed-rank test data for breast displacement while running on the treadmill with six different support levels respectively at 6km/h in the X, Y, Z-Planes and Residual displacement.

Y-plane

Wilcoxon Signed-rank test

	RB x Displacement HIU - RB x Displacement Control	RB x Displacement HIU - RB x Displacement Own	RB x Displacement HIU - RB x Displacement Low	RB x Displacement HIU - RB x Displacement Med	RB x Displacement HIU - RB x Displacement High
Z	-.663[b]	-.071[b]	-1.447[c]	-1.872[c]	-.932[b]
Asymp. Sig. (2-tailed)	,507	,943	,148	,061	,351

Residual displacement

Wilcoxon Signed-rank test

	RB y Displacement HIU - RB y Displacement Control	RB y Displacement HIU - RB y Displacement Own	RB y Displacement HIU - RB y Displacement Low	RB y Displacement HIU - RB y Displacement Med	RB y Displacement HIU - RB y Displacement High
Z	-1.165[b]	-1.042[c]	-.593[b]	-1.255[c]	-2.061[c]
Asymp. Sig. (2-tailed)	,244	,297	,553	,209	,039

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.
c. Based on negative ranks.

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior Posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

4.2.3.1 Lateral (X) displacement of the breast:

Lateral breast displacement at 8km/h

Lateral displacement of the breast at 8km/h was found to have the least amount of displacement while participants were wearing their Own bra (18.0mm) as well as while wearing the Medium impact support level bra (18.0mm). Maximal displacement was noted while the participants were wearing the Medium impact support level bra (65.0mm). The Medium impact support level bra had the lowest median for lateral breast displacement in relation to the other bras, showing that the best support at 8km/h for lateral displacement was experienced while wearing the Medium impact level support bra with a median of (27.0mm) see Table 4.5.

4.2.3.2 Anteroposterior (Y) displacement of the breast:

Anteroposterior displacement of the breast at 8km/h

Anteroposterior displacement of the breast at 8km/h was found to have the least amount of displacement while participants were wearing the Medium impact support level bra (13.0mm); with a maximum displacement while wearing the Low impact support level bra (77.0mm). Looking at the median for anteroposterior displacement at 8km/h shows that the best support was experienced while participants were wearing their Own bra with a median of (23.0mm) as well as while wearing the Medium impact support bra (23.0mm) see Table 4.5.

4.2.3.3Superior inferior (Z) displacement of the breast:

Superior inferior displacement of the breast at 8km/h

Superior inferior displacement in the breast at 8km/h was found to have the least amount of displacement while participants were wearing the HIU bra (11.0mm); with a maximum displacement in the Control with no bra (79.0mm). Looking at the median for superior inferior displacement at 8km/h shows that the best support was experienced while wearing the High impact level support bra with a median of (25.0mm) see Table 4.5.

4.2.3.4 Residual displacement of the breast

Residual displacement of the breast at 8km/h

Residual displacement in the breast at 8km/h was found to have the least amount of displacement while participants were wearing the HIU bra (7.0mm); with a maximum displacement with the no bra as the Control (66.0mm). Looking at the median for Residual displacement at 8km/h shows that the best support was experienced while participants were wearing their Own bra with a median of (23.0mm) see Table 4.5.

Table 4.5 Breast displacement while running on the treadmill with six different support levels respectively at 8km/h in the X, Y, Z-Planes and Residual displacement.

X-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	43	75	54,29	9,279	53,00
RB x Displacement Own	17	18	72	35,82	13,529	35,00
RB x Displacement Low	17	27	68	41,12	12,937	44,00
RB x Displacement Med	17	18	65	30,59	13,689	27,00
RB x Displacement High	17	20	67	33,59	12,971	30,00
RB x Displacement HIU	17	21	42	31,00	5,679	30,00

Y-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	35	67	46,65	8,448	45,00
RB x Displacement Own	17	17	56	29,65	13,592	23,00
RB x Displacement Low	17	18	77	43,06	18,846	49,00
RB x Displacement Med	17	13	72	29,53	16,804	23,00
RB x Displacement High	17	19	71	31,29	12,514	28,00
RB x Displacement HIU	17	16	73	33,00	14,565	30,00

Z-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	25	79	46,59	18,835	51,00
RB x Displacement Own	17	16	60	30,41	11,571	30,00
RB x Displacement Low	17	14	75	41,06	18,328	34,00
RB x Displacement Med	17	13	73	32,29	17,047	26,00
RB x Displacement High	17	12	54	29,76	14,263	25,00
RB x Displacement HIU	17	11	46	27,24	10,287	29,00

Residual Displacement

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	23	66	43,29	11,783	43,00
RB x Displacement Own	17	15	56	29,71	13,104	23,00
RB x Displacement Low	17	24	51	36,18	5,855	36,00
RB x Displacement Med	17	23	56	36,06	12,080	33,00
RB x Displacement High	17	21	55	30,71	8,622	29,00
RB x Displacement HIU	17	7	64	32,29	17,428	33,00

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

The Friedman's Test was used to compare the medians and identify if there was any difference between the medians. In the X-Plane a significant difference of p=0.00 was found showing that at least one bra performed differently, as well as in the Y-Plane p=0.001, Z-Plane p=0.012 and in Residual displacement with the significant difference p=0,041.

The Wilcoxon signed ranks test was then used to rank the data to calculate and identify which of the six bras showed a significant difference between the Control and the six support levels. A significant difference of p=0.00 and p=0.028 was found between the HIU bra in comparison to the Control and the HIU bra in comparison to the Low impact support level bra in the X-Plane respectively at 8km/h. In the Y-Plane a significant differences was found in the HIU bra compared with the Control p=0.009 as well as in the HIU bra compared to the Low impact support level bra with p=0.00. All other bras performed similarly in the X-Plane, Y-Plane, Z-Plane and Residual displacement with no significant difference found, see Table 4.6.

Table 4.6 Wilcoxon Signed-rank test data for breast displacement while running on the treadmill with six different support levels respectively at 8km/h in the X, Y, Z-Planes and Residual displacement.

X-plane

Wilcoxon Signed-rank test

	RB x Displacement HIU - RB x Displacement Control	RB x Displacement HIU - RB x Displacement Own	RB x Displacement HIU - RB x Displacement Low	RB x Displacement HIU - RB x Displacement Med	RB x Displacement HIU - RB x Displacement High
Z	-3.622[b]	-1.501[b]	-2.203[b]	-.958[c]	-.673[b]
Asymp. Sig. (2-tailed)	,000	,133	,028	,338	,501

Y-plane

Wilcoxon Signed-rank test

	RB y Displacement HIU - RB y Displacement Control	RB y Displacement HIU - RB y Displacement Own	RB y Displacement HIU - RB y Displacement Low	RB y Displacement HIU - RB y Displacement Med	RB y Displacement HIU - RB y Displacement High
Z	-2.628[b]	-.497[c]	-2.060[b]	-.621[c]	-.592[c]
Asymp. Sig. (2-tailed)	,009	,619	,039	,535	,554

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior Posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

4.2.4.1 Lateral (X) displacement of the breast:

Lateral breast displacement at 10km/h

Lateral displacement of the breast at 10km/h was found to have the least amount of displacement while participants were wearing the High impact support level bra and the HIU bra (17.0mm). Maximal displacement was noted while the participants were wearing no bra in the Control (117.0mm). The High impact support level bra had the lowest median for lateral breast displacement in relation to the other bras, showing that the best support at 10km/h for lateral displacement was experienced while wearing the High impact level support bra with a median of (32.0mm) see Table 4.7.

4.2.3.2 Anteroposterior (Y) displacement of the breast:

Anteroposterior displacement of the breast at 10km/h

Anteroposterior displacement of the breast at 10km/h was found to have the least amount of displacement while participants were wearing the High impact support level bra (15.0mm); with a maximum displacement while wearing their Own bra (99.0mm). Looking at the median for anteroposterior displacement at 10km/h shows that the best support was experienced while participants were wearing the HIU bra with a median of (29.0mm) see Table 4.7.

4.2.3.3Superior inferior (Z) displacement of the breast:

Superior inferior displacement of the breast at 10km/h

Superior inferior displacement in the breast at 10km/h was found to have the least amount of displacement while participants were wearing the Medium and High impact support level bras (13.0mm); with a maximum displacement in the Control (103.0mm). Looking at the median for superior inferior displacement at 10km/h shows that the best support was experienced while wearing the High impact level support bra with a median of (28.0mm) see Table 4.7.

4.2.3.4 Residual displacement of the breast

Residual displacement of the breast at 10km/h

Residual displacement in the breast at 10km/h was found to have the least amount of displacement while participants were wearing the Low impact support level bra (15.0mm); with a maximum displacement with the Control (100.0mm). Looking at the median for Residual displacement at 10km/h shows that the best support was experienced while participants were wearing the High impact support level bra with a median of (30.0mm) see Table 4.7.

Table 4.7 Breast displacement while running on the treadmill with six different support levels respectively at 10km/h in the X, Y, Z-Planes and Residual displacement.

X-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	33	117	58,24	22,775	51,00
RB x Displacement Own	17	28	69	44,65	13,688	40,00
RB x Displacement Low	17	34	78	46,24	11,766	43,00
RB x Displacement Med	17	26	80	45,29	14,251	41,00
RB x Displacement High	17	17	55	34,06	9,972	32,00
RB x Displacement HIU	17	17	84	44,12	17,066	38,00

Y-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	33	85	60,82	15,018	61,00
RB x Displacement Own	17	27	99	47,59	21,843	40,00
RB x Displacement Low	17	22	76	43,71	11,482	41,00
RB x Displacement Med	17	26	61	36,82	10,620	32,00
RB x Displacement High	17	15	55	33,00	9,862	31,00
RB x Displacement HIU	17	19	69	37,00	16,260	29,00

Z-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	29	103	66,41	18,997	68,00
RB x Displacement Own	17	19	67	46,24	15,189	47,00
RB x Displacement Low	17	20	62	43,24	13,041	44,00
RB x Displacement Med	17	13	92	41,82	21,815	34,00
RB x Displacement High	17	13	52	30,24	10,545	28,00
RB x Displacement HIU	17	14	74	34,53	15,195	32,00

Residual Displacement

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	45	100	71,82	14,997	76,00
RB x Displacement Own	17	22	77	42,94	14,515	41,00
RB x Displacement Low	17	15	72	49,82	16,637	51,00
RB x Displacement Med	17	23	60	41,06	10,633	40,00
RB x Displacement High	17	20	65	34,71	11,899	30,00
RB x Displacement HIU	17	22	61	36,53	11,785	35,00

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

The Friedman's Test was used to compare the medians and identify if there was any difference between the medians. In the X-Plane, Y-Plane, Z-Plane as well as in Residual displacement a significant difference of p=0.00 was found showing that at least one bra performed differently.

A significant difference of p=0.039 was found between the HIU bra in comparison to the High impact support level bra in the X-Plane. In the Y-Plane a significant difference was found with the HIU bra in comparison to the Control with p= 0.002. In the Z-Plane a significant difference was found with the HIU bra in comparison to the Control with p= 0.001 and in the HIU bra with comparison to participants Own bra with p=0.044. All other bras performed similarly in the X-Plane, Y-Plane, Z-Plane and Residual displacement with no significant difference found, see Table 4.8. The Wilcoxon signed ranks test was used to rank the data, calculate and identify the above significant differences between the Control and the six support levels.

Table 4.8 Wilcoxon Signed-rank test data for breast displacement while running on the treadmill with six different support levels respectively at 10km/h in the X, Y, Z-Planes and Residual displacement.

X-plane

Wilcoxon Signed-rank test

	RB x Displacement HIU - RB x Displacement Control	RB x Displacement HIU - RB x Displacement Own	RB x Displacement HIU - RB x Displacement Low	RB x Displacement HIU - RB x Displacement Med	RB x Displacement HIU - RB x Displacement High
Z	-1.849[b]	-.517[b]	-.426[b]	-.310[b]	-2.061[c]
Asymp. Sig. (2-tailed)	,064	,605	,670	,756	,039

Y-plane

Wilcoxon Signed-rank test

	RB y Displacement HIU - RB y Displacement Control	RB y Displacement HIU - RB y Displacement Own	RB y Displacement HIU - RB y Displacement Low	RB y Displacement HIU - RB y Displacement Med	RB y Displacement HIU - RB y Displacement High
Z	-3.102[b]	-1.065[b]	-1.777[b]	-.237[b]	-.569[c]
Asymp. Sig. (2-tailed)	,002	,287	,076	,813	,569

Z-plane

Test Statistics[a]

	RB y Displacement HIU - RB y Displacement Control	RB y Displacement HIU - RB y Displacement Own	RB y Displacement HIU - RB y Displacement Low	RB y Displacement HIU - RB y Displacement Med	RB y Displacement HIU - RB y Displacement High
Z	-3.386[b]	-2.018[b]	-1.705[b]	-.653[b]	-.829[c]
Asymp. Sig. (2-tailed)	,001	,044	,088	,513	,407

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior Posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

This data illustrates that in all planes of movement as well as with Residual displacement the HIU demonstrated the best support while running on the treadmill at 4, 6, 8 and 10km/h in comparison to wearing the lower level support bras.

4.3 TWO STEP STAR JUMP

Descriptive statistics were used to calculate the minimum, maximum and mean displacement in millimetres (mm) of the breasts while completing a Two-Step Star Jump test while wearing four different level support bras, participants Own bra and no bra for the Control.

4.3.1 Two-Step Star Jump test, Residual displacement:

Tests for normality where performed using the descriptive data. Non-parametric statistics were then used as a significant difference of $p \leq 0.005$ was found (Table 4.9). The medians (due to asymmetrical data distribution) were then tested using the Friedman test to determine if at least one bra performed differently to the others. The Wilcoxon Signed rank test was then done to identify which bra in particular showed a significant difference and in which plane. See Table 4.10.

A significant difference of $p=0.00$ was found between the HIU bra in comparison to the Control the HIU bra and participants Own bra in the X-Plane ($p=0.00$). In the Y-Plane a significant difference was found with the HIU bra in comparison to the Control and Medium impact support level bra ($p=0.00$). In the Z-Plane a significant difference was found with the Control and the HIU bra in comparison to the participants, Own bra as well as in comparison with the Low impact support level bra ($p=0.00$). Residual displacement showed a significant difference with HIU bra compared to the Control, participants Own bra, Low Impact support level bra, Medium impact support level bra, as well as the High impact support level bra ($p=0.00$). All other bras performed similarly in the X-Plane, Y-Plane, Z-Plane and Residual displacement with no significant difference found, see Table 4.10.

This data illustrates that in all planes of movement as well as with Residual displacement the HIU bra demonstrated the best support while performing the Two-Step Star Jump test in relation to the lower level support bras. However no significant difference was found when comparing the Medium and High impact support level bras to the HIU bra.

Table 4.9 Breast displacement while completing a Two-Step Star Jump test with six different support levels respectively in the X, Y, Z-Planes and Residual displacement.

X-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	31,27	55,41	39,95	7,07	38,25
RB x Displacement Own	17	11,78	33,47	20,32	5,02	21,03
RB x Displacement Low	17	21,62	29,66	24,22	2,32	23,36
RB x Displacement Med	17	20,38	42,22	29,69	5,46	27,52
RB x Displacement High	17	18,63	26,35	22,82	2,49	22,95
RB x Displacement HIU	17	18,63	26,97	23,03	2,39	22,48

Y-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	35,17	75,68	43,56	9,20	41,10
RB x Displacement Own	17	9,59	21,69	14,18	3,86	13,39
RB x Displacement Low	17	22,54	60,55	27,55	9,21	24,84
RB x Displacement Med	17	20,11	41,22	32,19	6,31	31,60
RB x Displacement High	17	18,75	59,44	28,83	9,66	25,82
RB x Displacement HIU	17	21,04	29,26	24,59	2,65	24,24

Z-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	23,29	74,46	58,44	10,24	60,78
RB x Displacement Own	17	26,16	49,04	40,63	6,31	41,25
RB x Displacement Low	17	30,05	56,38	36,75	6,31	34,27
RB x Displacement Med	17	16,82	36,79	25,13	6,07	23,25
RB x Displacement High	17	21,18	40,28	30,56	4,87	30,03
RB x Displacement HIU	17	19,81	36,63	27,08	5,14	25,36

Residual Displacement

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Displacement Control	17	22,88	58,96	50,15	9,37	54,00
RB x Displacement Own	17	22,87	46,58	39,50	6,92	42,42
RB x Displacement Low	17	31,63	70,93	46,91	11,35	45,24
RB x Displacement Med	17	28,65	45,24	36,91	5,37	36,36
RB x Displacement High	17	23,26	62,18	35,61	10,06	35,00
RB x Displacement HIU	17	19,50	55,00	33,28	9,92	32,29

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

Table 4.10 Breast displacement while completing a Two-Step Star Jump test with six different support levels respectively in the X, Y, Z-Planes and Residual displacement.

X-plane

	RB x % Reduction HIU vs Control-RB x %Reduction Own vs Control	RB x %Reduction HIU vs Control - RB x %Reduction Low vs Control	RB x % Reduction HIU vs Control - RB x %Reduction Med vs Control	RB x %Reduction HIU vs Control - RB x %Reduction High vs Control
Z	-3.148b	-1.775b	-3.243b	-.686c
Asymp. Sig. (2-tailed)	0.00	0.08	0.00	0.49

Y-plane

	RB x % Reduction HIU vs Control - RB x %Reduction Own vs Control	RB x %Reduction HIU vs Control - RB x %Reduction Low vs Control	RB x % Reduction HIU vs Control - RB x %Reduction Med vs Control	RB x %Reduction HIU vs Control - RB x %Reduction High vs Control
Z	-.970b	-.686c	-3.101c	-1.444c
Asymp. Sig. (2-tailed)	0.33	0.49	0.00	0.15

Z-plane

	RB x % Reduction HIU vs Control - RB x %Reduction Own vs Control	RB x %Reduction HIU vs Control - RB x %Reduction Low vs Control	RB x % Reduction HIU vs Control - RB x %Reduction Med vs Control	RB x %Reduction HIU vs Control - RB x %Reduction High vs Control
Z	-3.574b	-3.337b	-.970c	-1.681b
Asymp. Sig. (2-tailed)	0.00	0.00	0.33	0.09

Residual Displacement

	RB x % Reduction HIU vs Control - RB x %Reduction Own vs Control	RB x %Reduction HIU vs Control - RB x %Reduction Low vs Control	RB x % Reduction HIU vs Control - RB x %Reduction Med vs Control	RB x %Reduction HIU vs Control - RB x %Reduction High vs Control
Z	-3.006b	-3.621b	-2.343b	-3.337b
Asymp. Sig. (2-tailed)	0.00	0.00	0.02	0.00

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior Posterior displacement, Y-Plane,

4.3.2 Two-Step Star Jump test, percent reduction:

Tests for normality where performed using the descriptive data followed by non-parametric statistics as a significant difference of p≤0.005 was found. The medians were then tested using the Friedman test to determine if at least one bra performed differently to the others. The Wilcoxon Signed rank test was done to identify which bra in particular showed a significant difference and in which plane. See Table 4.11.

A significant difference of p=0.00 was found between the HIU bra in comparison to the Control as well as between the HIU bra in comparison to the Medium impact support level bra and participants Own bra in the X-Plane (p=0.00). In the Y-Plane a significant difference was found with the HIU bra in comparison to the Control and Medium impact support level bra (p=0.00). In the Z-Plane a significant difference was found with the HIU bra in comparison to the Control, Own bra as well as in comparison with the Low impact support level bra (p=0.00). Residual displacement showed a significant difference with HIU bra compared to all the bras as well as the Control (p=0.00), while the significant difference for the HIU bra compared to the Medium impact support level was p=0.002. All other bras performed similarly in the X-Plane, Y-Plane, Z-Plane with no significant difference found, see Table 4.12.

This data illustrates that percent reduction in all planes of movement as well as with Residual displacement the HIU bra demonstrated the best support while performing the Two-Step Star Jump test.

Table 4.11 Percent reduction of breast displacement while completing a Two-Step Star Jump test with six different support levels respectively in the X, Y, Z-Planes and Residual displacement.

X-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Percent Reduction HIU vs Control	17	19,86	60,86	40,90	10,60	38,33
RB x Percent Reduction HIU vs Own	17	-125,94	36,16	-20,91	37,62	-13,58
RB x Percent Reduction HIU vs Low	17	-14,98	23,24	4,40	11,26	2,72
RB x Percent Reduction HIU vs Med	17	-9,72	49,39	19,73	17,61	21,57
RB x Percent Reduction HIU vs High	17	-21,07	25,76	-2,00	14,22	-3,05

Y-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Percent Reduction HIU vs Control	17	17,80	68,74	46,69	14,29	41,23
RB x Percent Reduction HIU vs Own	17	-47,37	68,56	34,45	25,17	-91,68
RB x Percent Reduction HIU vs Low	17	-3,33	58,37	24,69	15,72	0,85
RB x Percent Reduction HIU vs Med	17	-49,74	67,80	31,18	28,10	25,46
RB x Percent Reduction HIU vs High	17	26,29	61,56	42,14	9,63	6,30

Z-plane

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Percent Reduction HIU vs Control	17	-17,31	56,96	20,57	16,52	17,95
RB x Percent Reduction HIU vs Own	17	-29,93	53,97	34,41	19,55	39,32
RB x Percent Reduction HIU vs Low	17	26,63	67,94	55,63	13,00	58,30
RB x Percent Reduction HIU vs Med	17	-20,84	74,78	37,83	28,17	45,54
RB x Percent Reduction HIU vs High	17	-4,17	67,41	51,39	16,75	53,51

Residual Displacement

	N	Minimum	Maximum	Mean	Std. Deviation	Median
RB x Percent Reduction HIU vs Control	17	-18,71	58,11	18,76	18,77	20,09
RB x Percent Reduction HIU vs Own	17	-210,07	46,36	-2,23	58,13	16,64
RB x Percent Reduction HIU vs Low	17	-10,33	63,03	40,86	17,95	44,43
RB x Percent Reduction HIU vs Med	17	-83,95	57,38	23,30	37,37	35,68
RB x Percent Reduction HIU vs High	17	-29,50	60,99	35,79	21,16	42,76

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

Table 4.12 Percent Reduction of breast displacement while completing a Two-Step Star Jump test with six different support levels respectively in the X, Y, Z-Planes and Residual displacement.

X-plane

Wilcoxon Signed-rank test

	RB x Percent Reduction HIU vs Control - RB x Percent Reduction Own vs Control	RB x Percent Reduction HIU vs Control - RB x Percent Reduction Low vs Control	RB x Percent Reduction HIU vs Control - RB x Percent Reduction Med vs Control	RB x Percent Reduction HIU vs Control - RB x Percent Reduction High vs Control
Z	-3.148[b]	-1.775[b]	-3.243[b]	-.686[c]
Asymp. Sig. (2-tailed)	0,00	0,08	0,00	0,49

Y-plane

Wilcoxon Signed-rank test

	RB y Percent Reduction HIU vs Control - RB y Percent Reduction Own vs Control	RB y Percent Reduction HIU vs Control - RB y Percent Reduction Low vs Control	RB y Percent Reduction HIU vs Control - RB y Percent Reduction Med vs Control	RB y Percent Reduction HIU vs Control - RB y Percent Reduction High vs Control
Z	-.970[b]	-.686[c]	-3.101[c]	-1.444[c]
Asymp. Sig. (2-tailed)	0,33	0,49	0,00	0,15

Z-plane

Wilcoxon Signed-rank test

	RB x Percent Reduction HIU vs Control - RB x Percent Reduction Own vs Control	RB x Percent Reduction HIU vs Control - RB x Percent Reduction Low vs Control	RB x Percent Reduction HIU vs Control - RB x Percent Reduction Med vs Control	RB x Percent Reduction HIU vs Control - RB x Percent Reduction High vs Control
Z	-3.574[b]	-3.337[b]	-.970[c]	-1.681[b]
Asymp. Sig. (2-tailed)	0,00	0,00	0,33	0,09

Residual Displacement

Wilcoxon Signed-rank test

	RB y Percent Reduction HIU vs Control - RB y Percent Reduction Own vs Control	RB y Percent Reduction HIU vs Control - RB y Percent Reduction Low vs Control	RB y Percent Reduction HIU vs Control - RB y Percent Reduction Med vs Control	RB y Percent Reduction HIU vs Control - RB y Percent Reduction High vs Control
Z	-3.006[b]	-3.621[b]	-2.343[b]	-3.337[b]
Asymp. Sig. (2-tailed)	0,00	0,00	0,02	0,00

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.
c. Based on negative ranks.

RB –Right breast, Control- No bra, Own-Own bra, Low- Low impact support bra, Med- Medium impact support bra, High- high impact support bra, HIU- High impact ultimate support bra. X-plane-Lateral displacement, Y-Plane- Anterior Posterior displacement, Y-Plane, Superior inferior displacement, Residual displacement- Overall breast displacement.

4.4 PERCEPTUAL EVALUATION

Following each test participants were given the opportunity to assess bra comfort, breast comfort, perceived support, fit, likes and dislikes. Each participant had an adequate amount of time to rest before the next bra condition (Appendix F).

Subjective Response:

Breast comfort, breast pain and bra comfort:

Table 7.1 shows ratings of breast comfort, breast pain and bra comfort

- Breast comfort: 0 being very uncomfortable and 10 being very comfortable.
- Bra comfort: 0 being very uncomfortable and 10 being very comfortable.
- Pain: 0 being no pain and 10 being very painful.

In terms of breast comfort during the trials participants rated their Own bras the lowest at 7.2 with the HIU bra rated the highest 9.1, closely followed by High impact support level bra with 8.7 (not taking into account the Control). Breast pain intensity was measured the highest in the Control and the Low impact bra at 2.0 and 2.2 respectively, the HIU bra was rated with the lowest pain index of 0.4. A similar trend was seen in the comfort rating of the bras and how they felt during the trial; the HIU bra was rated the most comfortable 8.7 with the High impact support level bra coming in second with a rating of 8.4. Participants rated their Own bra as the least comfortable during the trial 7.1.

Bra supportiveness and fit:

Table 4.13 shows how participants rated the fit and support of each bra during each condition with 0 being unsupportive and an ill fit and 10 being a very supportive and good fit.

The Low impact bra and participants Own bra were rated the least supportive with a rating of 6.8 as well as in fit with 6.7. The HIU bra was rated the most supportive bra 9.3 while the High impact support level bra was rated the best fitted bra with an average rating of 9.0 the HIU bra came in second with a rating of 8.6 for fit.

Table 4.13: Subjective responses of participants

Questions	Means
Q1 No Bra: How comfortable your breast felt during the trial?	3.6
Q2 No Bra: The intensity of breast pain felt during the trial?	3.1
Q1 Own Bra: How comfortable your breast felt during the trial?	7.2
Q2 Own Bra: The intensity of breast pain felt during the trial?	2.0
Q3 Own Bra: How comfortable did the bra feel during the trial?	7.1
Q4 Own Bra: How supportive did the bra feel during the trial?	6.8
Q5 Own Bra: What was the fit of the bra like?	6.7
Q1 Low/ Light Impact Bra: How comfortable your breast felt during the trial?	7.5
Q2 Low/ Light Impact Bra: The intensity of breast pain felt during the trial?	2.2
Q3 Low/ Light Impact Bra: How comfortable did the bra feel during the trial?	7.2
Q4 Low/ Light Impact Bra: How supportive did the bra feel during the trial?	6.8
Q5 Low/ Light Impact Bra: What was the fit of the bra like?	7.7
Q1 Medium Impact Bra: How comfortable your breast felt during the trial?	8.2
Q2 Medium Impact Bra: The intensity of breast pain felt during the trial?	1.5
Q3 Medium Impact Bra: How comfortable did the bra feel during the trial?	8.1
Q4 Medium Impact Bra: How supportive did the bra feel during the trial?	7.8
Q5 Medium Impact Bra: What was the fit of the bra like?	8.1
Q1 HIA Impact Bra: How comfortable your breast felt during the trial?	8.7
Q2 HIA Impact Bra: The intensity of breast pain felt during the trial?	0.9
Q3 HIA Impact Bra: How comfortable did the bra feel during the trial?	8.4
Q4 HIA Impact Bra: How supportive did the bra feel during the trial?	8.6
Q5 HIA Impact Bra: What was the fit of the bra like?	9.0
Q1 HIU Impact Bra: How comfortable your breast felt during the trial?	9.1
Q2 HIU Impact Bra: The intensity of breast pain felt during the trial?	0.4
Q3 HIU Impact Bra: How comfortable did the bra feel during the trial?	8.7
Q4 HIU Impact Bra: How supportive did the bra feel during the trial?	9.3
Q5 HIU Impact Bra: What was the fit of the bra like?	8.6

Additional subjective comments

Light impact

Likes:	*Dislikes:*
"Design and straps"	"Not supportive enough"
"Criss-cross straps"	"High cut by armpit"
"Comfortable on skin"	"Too loose around breasts"
"Flexible"	"Difficult to put on"
"No seams"	
"Like the fabric"	
"Good fit"	
"Easy to put on"	
"Secured straps"	
"Colour"	

Medium impact

Likes:	*Dislikes:*
"Nice looking bra"	"No adjustable straps"
"Like the feel"	"Too loose around breasts"
"Colour and style"	"Material to thick"
"Strap and back clasp"	"Cut to low in the front"
"Like the fabric"	"Difficult to fasten"
"Cut and padding"	
"Design"	

High Impact

Likes:	*Dislikes:*
"Very supportive"	"No padding"
"Nice fit"	"Too many seams"
"Thinner adjustable straps"	"Couldn't make tight enough"
"Feels like normal bra"	"Doesn't mould to the breast"
"Shape in front"	
"Nice fabric"	
"Like the look and design"	
"Like the straps"	
"Can un-clip to put it on"	

High Impact Ultimate

Likes	*Dislikes*
"Straps and fabric very supportive"	"Too tight"
"Design and fabric"	"Material gathered around cup"
"Clip at back"	"Difficult to put on"
"Very nice look"	"Chest strap a bit tight"
"Like the straps at the back"	"Too many straps"
"Adjustable thick straps"	"No padding on cup"
	"Cups not fitted enough"

Own bra

Likes	*Dislikes*
"Comfortable, doesn't cut into my skin"	"Too tight" (Puma)
"The look" (Puma)	"Straps loosen while training"
"The look" (Maxed)	"Uncomfortable support" (Triumph)
"Fabric"	
"Colour"	*Suggestions for improvements to the product*
"Slightly padded" (Mr Price sport)	"Stretched a bit"
"Took shape of body" (Skinny)	"Better fit for each bra size" (Puma)
"Not that supportive, fabric not that nice" (Tri-action)	"Softer fabric" (Skinny)
"Not tight enough" (Maxed)	
"Too tight" (Skinny)	
"Straps not well fitted"	
"More support needed" (Tri-action)	
"Stronger fabric and more support" (Maxed)	
"Better support" (Triumph)	
"The look" (Tri-action)	
"Design and look"	
"Comfortable straps"	
"Adjustable straps"	

4.5 DISCUSSION

1.) Breast displacement at 4km/h

While running on the treadmill each of the different shock absorber support level bras offered support at different levels of exercise intensity. At 0-4km/h there is little strain on the breasts and the surrounding tissue. Residual displacement was found to be lowest (Median) when wearing the HIU bra, see Figure 4.1. However significant differences ($p<0.05$) where only found when the HIU bra was compared with the Low impact support level bra and Control in both the X and Y-Planes, see Figure 4.2.

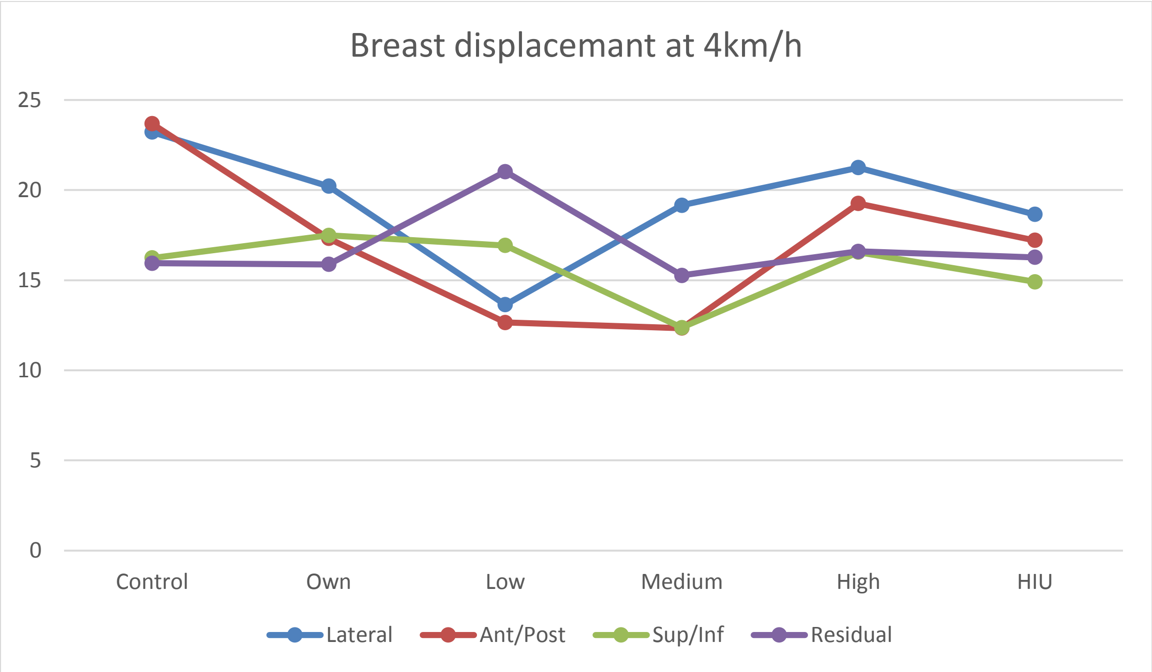


Figure 4.1 Breast displacement in the X, Y, Z- Planes and Residual displacement at 4km/h.

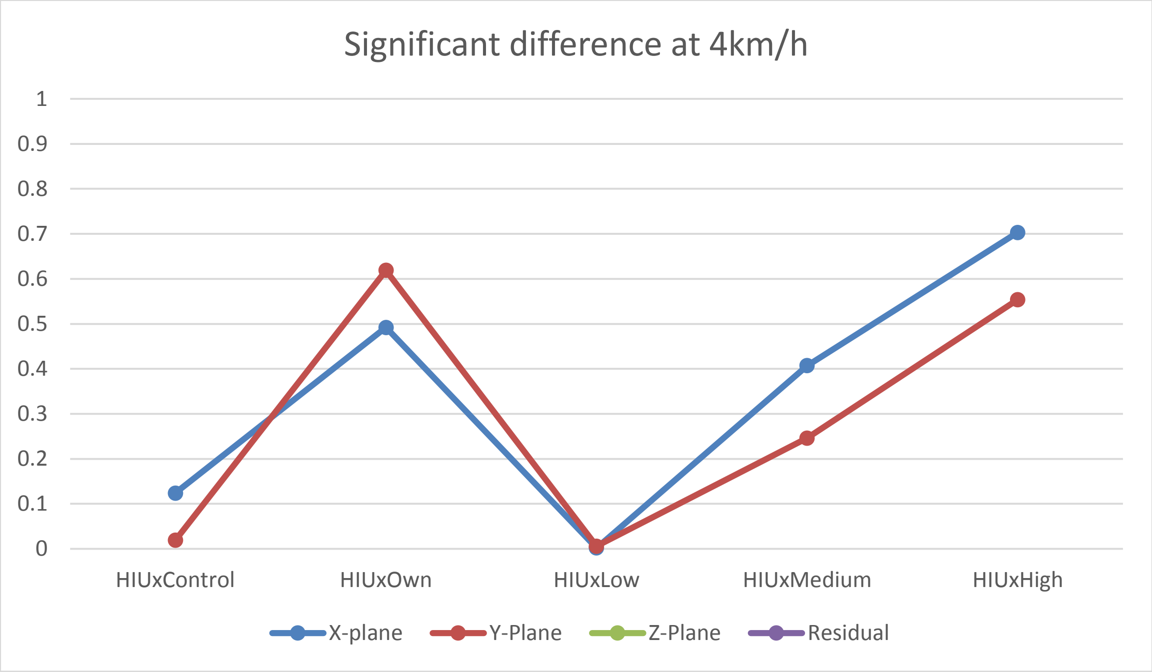


Figure 4.2 Significant difference in breast displacement in the X, Y, Z-Planes and Residual displacement at 4km/h.

2.) Breast displacement at 6km/h

At this point in acceleration breast tissue is seen to experience greater displacement in all planes of movement, with the greatest values found in lateral displacement across all conditions. The HIU bra was shown to be the most effective at decreasing tissue displacement in all planes, however in Residual displacement the High impact support bra showed the best support when evaluating the Median, see Figure 4.3. A significant difference ($p<0.05$) was found when comparing the HIU bra to the High impact support level bra, see Figure 4.4.

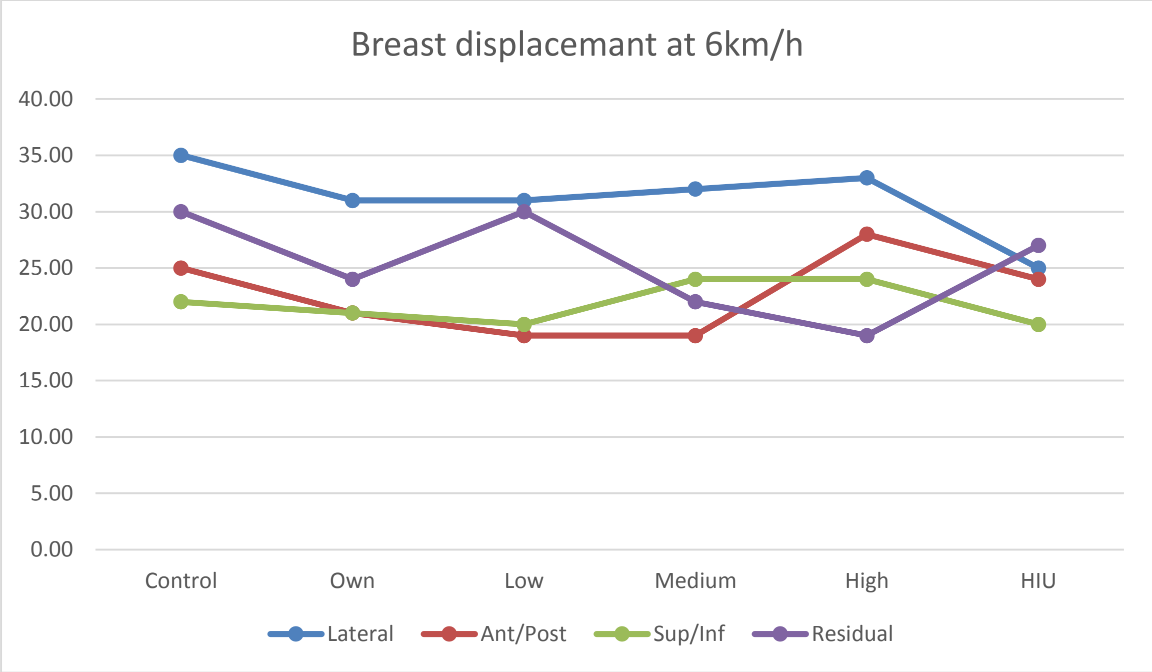


Figure 4.3 Breast displacement in the X, Y, Z-Planes and Residual displacement at 6km/h.

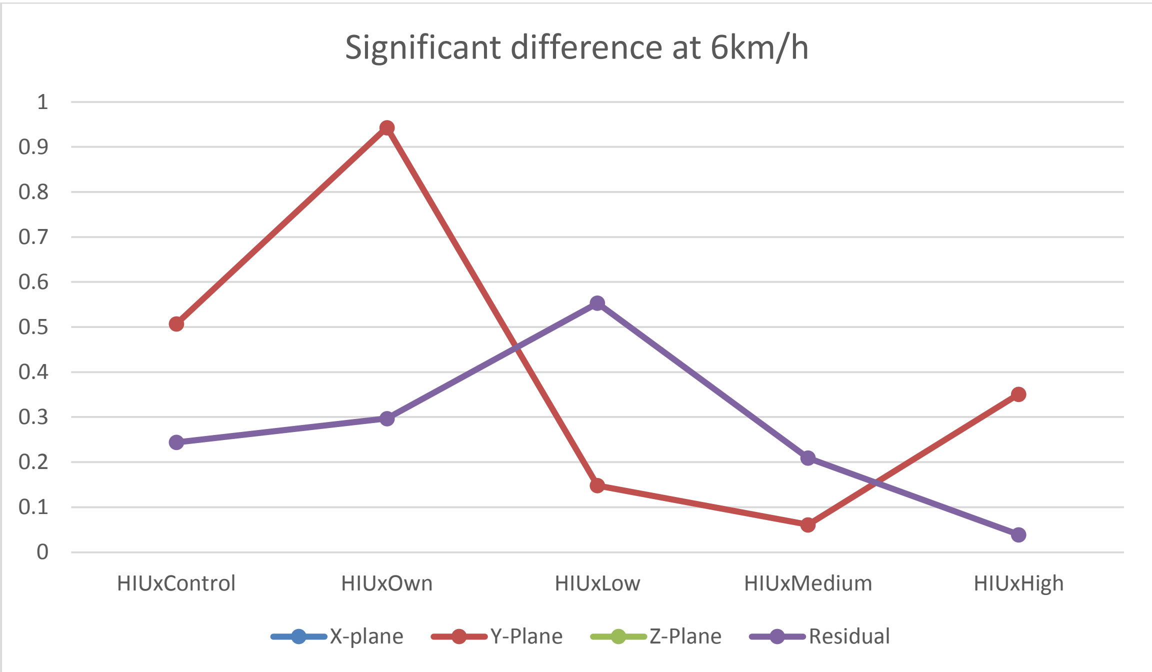


Figure 4.4 Significant difference in breast displacement in the X, Y, Z-Planes and Residual displacement at 6km/h.

3.) Breast displacement at 8km/h

At 8km/h the Medium impact support level bra, High impact support level bra and HIU bra offer the most support for breast displacement in all planes. This is on observation of the Median, see Figure 4.5. When looking at Figure 4.6 the only significant difference ($p<0.05$) was found between the HIU bra, Control and Own bra. With HIU bra demonstrating the best support in the X and Y-Planes. No significance ($p>0.05$) was noted in the other planes of movement.

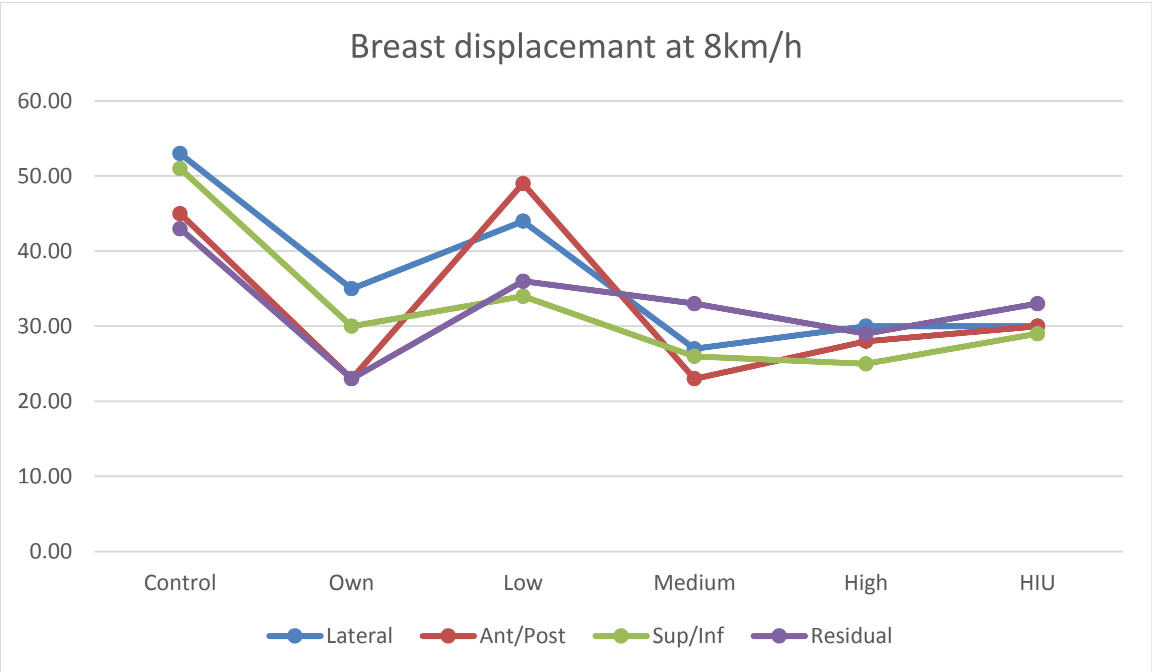


Figure 4.5 Breast displacement in the X, Y, Z- Planes and Residual displacement at 8km/h.

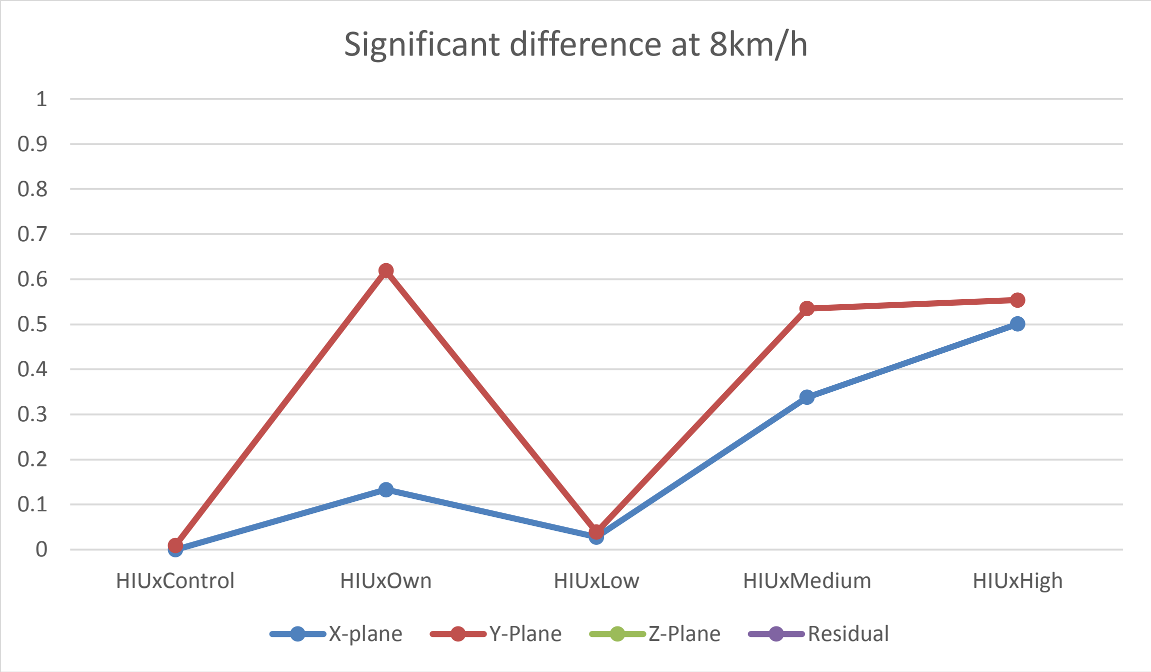


Figure 4.6 Significant difference in breast displacement in the X, Y, Z-Planes and Residual displacement at 8km/h.

4.) Breast displacement at 10km/h

The Median values at 10km/h indicate that the High impact support level bra offers the best support in all planes of movement (Figure 4.7) However when looking at the significant differences the HIU bra does in fact offer the best support over the High impact support level bra (Figure 4.8). This is indicative for the Lower level support bras as well as the High impact support level bra.

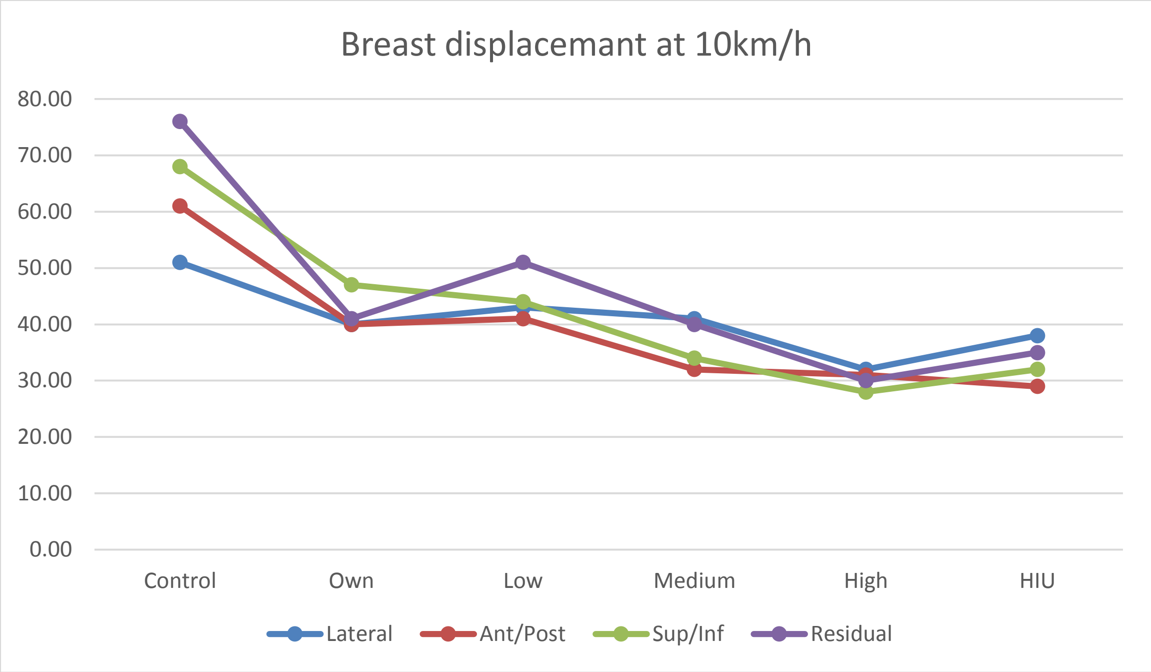


Figure 4.7 Breast displacement in the X, Y, Z-Planes and Residual displacement at 10km/h.

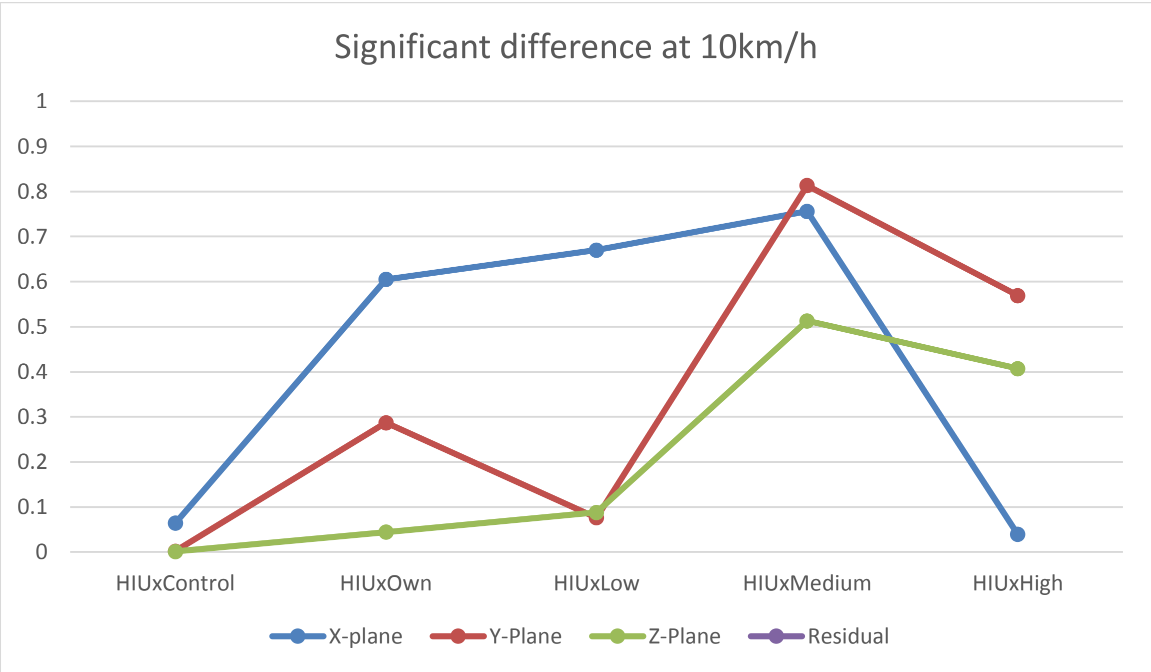
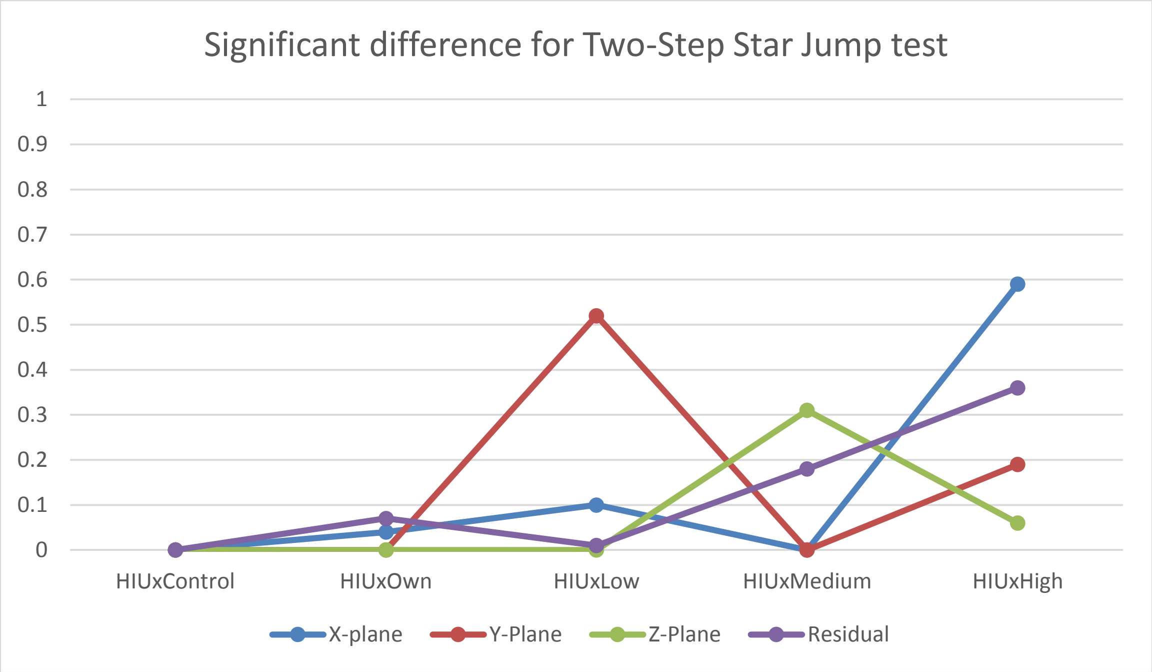


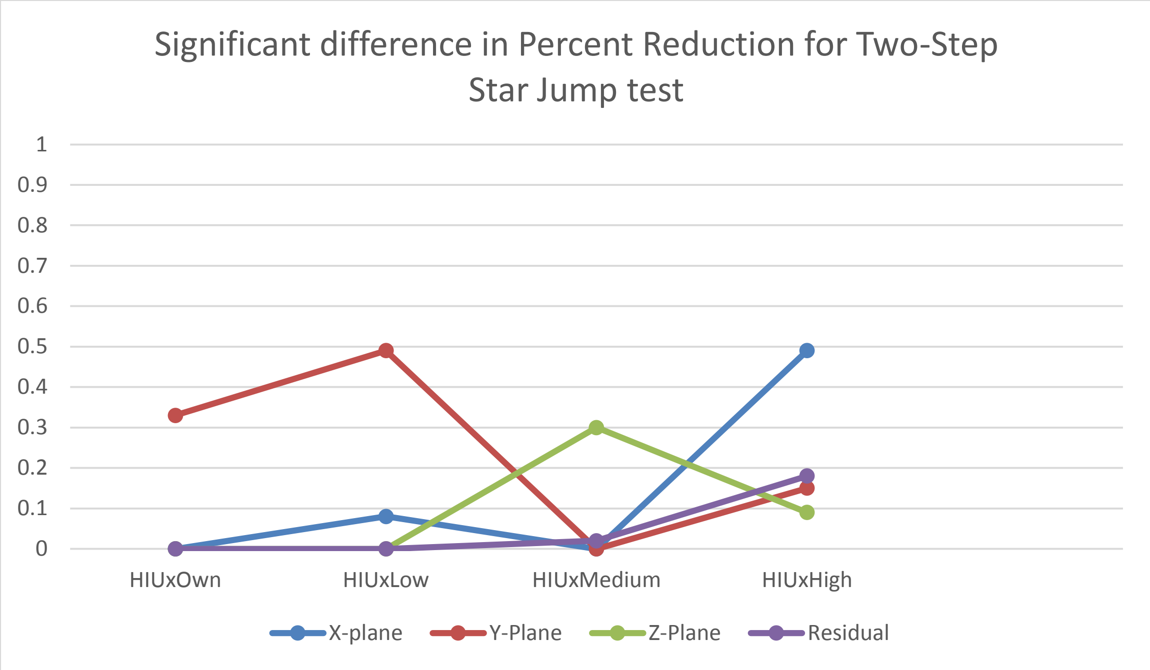
Figure 4.8 Significant difference in breast displacement in the X, Y, Z-Planes and Residual displacement at 10km/h.

5.) Two Step Star Jump test

The Two-Step Star Jump test is a valuable test in evaluating displacement in all planes (Bridgman *et al*., 2010). Regarding displacement of the breast tissue in the X, Y, Z-Planes and Residual displacement, the HIU bra demonstrated the best support in relation to all other conditions. Percent reduction was also evaluated and again demonstrated like results. The HIU bra demonstrated superior performance over all conditions for Residual displacement showing the greatest decline in displacement. See Figure 4.9; 4.10.



<u>Figure 4.9</u> Significant difference in breast displacement in the X, Y, Z-Planes and Residual displacement while performing the Two-Step Star Jump test.



<u>Figure 4.10</u> Significant difference in percent reduction of Breast displacement in the X, Y, Z-Planes and Residual displacement while performing the Two-Step Star Jump test.

Little substantial breast displacement or associated breast pain was noted at 4km/h, the HIU bra showed the greatest support in both lateral and anteroposterior displacement in comparison to the Control and Low impact support level bra, with no significant difference ($p>0.05$) found in comparison to the other support level bras (Scurr *et al.*, 2011). At 6km/h tissue displacement increased and a significant difference ($p<0.05$) was identified between the HIU bra and the High impact support level bra for Residual displacement. Showing that at 6km/h the HIU bra was most effective in decreasing the amount of Residual displacement. Between 8-10km/h breast tissue displacement plateaued. As a result of this plateau we can see that the relationship between breast velocity and breast discomfort is limited (Bridgman *et al.*, 2010; Scurr *et al.*, 2011). Earlier research by Scurr *et al* (2011) found the equivalent plateau at 10km/h. This questions the need for further research into activity specific breast support in lower thresholds of activity (Scurr *et al.*, 2011). Interestingly previous research has reported that as acceleration increased breast discomfort decreased indicating that breast acceleration is not a sensitive measure (Bridgman *et al.*, 2010). For 8km/h the HIU bra demonstrated the greatest level of support in the X and Y-Planes in relation to both the Control and the Low impact support level bra. No significant difference ($p<0.05$) was found for the Medium and High impact support level bras or in the other planes of movement. This trend continued with the HIU bra at 10km/h, finding again a significant difference ($p<0.05$) in support in comparison to the Control in the Y and Z-Planes, High impact support level bra in the X-Plane, and Own bra in the Z-Plane.

It can be noted that from the above data that as breast support is increased breast displacement is decreased, this is however not the case for the increase in acceleration (Scurr *et al*., 2011). Breast extension was experienced in all breast support conditions with treadmill running as well as with the Two-Step Star Jump test. At a closer look at the collected data at the different speeds along with past research it cannot equivocally be stated that as treadmill speed increases so does the velocity and acceleration of breast displacement ((Bridgman *et al*., 2010; Scurr *et al*., 2011). Specific changes in upper-body gait such as trunk rotation and oscillation are specific to individuals gait pattern. This creates a degree of biological or systematic variance (Milligan *et al*., 2011). This suggests that although the bras are effectively reducing the change in magnitude of breast displacement they are not having an effect on the movement pattern of the breast in its self (Scurr *et al*., 2011). This opens up research to be done on sport specific sports bra design. In addition to the above variables, exercise induced breast pain as a result of an increase or decrease of muscle activation and tension as a result of increased velocity with treadmill running and Two-Step Star Jumping was not considered in this study (Milligan *et al*., 2014).

Breast kinematic research has primarily been aimed at treadmill running. Focus has been on vertical displacement of the breast tissue at limited speeds (Bridgman *et al*., 2010). There are two phases in the movement performed for the Two-Step Star Jump test. Phase one is comprised of the upward stage where lower limbs push off the ground and arms are abducted away from the body, breasts are displaced in the X, Y and Z-Planes. In the downward stage breast displacement is medial and downward as lower limbs make contact with the ground (Bridgman *et al*., 2010). Phase two showed displacement of breast tissue medially (X-plane) and vertically (Z-plane) as upper and lower limbs are adducted, with the downward phase breast tissue was displaced posteriorly (Y-Plane). Earlier research has established that with the Two-Step Star Jump test more displacement of breast tissue is experienced in the vertical (Z) plane. Bridgman *et al* (2010) found that 58% of all breast displacement was predominately in the vertical (Z) plane with bare-breasted kinematics and displayed a moderate correlation to breast discomfort (Bridgman *et al*., 2010). Comparisons of displacement with different breast supports while performing a Two-Step Star Jump test have not been conducted in previous studies and leave room for more research to be done to more clearly define what support is required in all movement patterns.

One of the aims of this study was to identify which bra would give the most support during the performance of the Two-Step Star Jump test. Reports have suggested that the Two-Step Star Jump test is a whole body movement exercise and causes excessive movement of the breast tissue and thus can be used as a diagnostic tool to determine the effectiveness of the bra (Bridgman *et al*., 2010). The present study aimed to identify which bra support would best reduce breast displacement of the breast in all planes when compared to the base values established with the bare-breasted Two-Step Star Jump test. The displacement experienced by the breast tissue in the Control, Own bra and Low impact support bras where higher in the X and Y-Plane than in the Z-Plane demonstrating that with the correct support, vertical displacement can be significantly reduced and controlled. The reduction in vertical displacement experienced with the correct breast support is a step forward in the bra design tested in the current study, as prior research has stated that vertical displacement is greater and in need of more support with Two-Step Star Jumping (Bridgman *et al*., 2010).

In this study the HIU bra performed the best in all planes in the Two-Step Star Jump test; decreasing the displacement of the breast tissue significantly compared to the Control in the X, and Y-Planes, Medium Impact support level bra in the X-Plane, Own bra and Low impact support level bra in the Y-Plane. This shows that the HIU bra offers the best support not only with treadmill running at different speeds but in a complex whole body movement as well. This supports the assertion made in previous studies that the Two- Step Star jump test may indeed aid in the understanding of the direction and magnitude of bare-breasted displacement in multiple planes and thus can be used as a indicative tool in determining functionality and comfort of a sports bra as the test is easily repeated and demonstrates the same multiplanar pattern of movement with re-testing (Bridgman *et al*., 2010).

As in other studies reported separating the data from breast kinematics into different planes (X,Y, and Z-Planes) enables a clearer understanding of the kinematic differences in percent reduction recorded in each plane (Milligan, Scurr, Mills & Wood, 2011). Recent research has suggested that the biggest contributor to an increase in breast displacement is not in the acceleration experienced by the breast tissue but rather is influenced the most by the vertical displacement or displacement in the Z-Plane (Bridgman *et al*., 2010; Scurr *et al*., 2010). This coincides with the present study indicating that monitoring the velocity of the breast and percentage reduction is of greater importance in the design and manufacturing of sports specific bras (Scurr *et al*., 2010).

Considering the design of the bras it appears they are more focused on preventing mediolateral and anteroposterior displacement. The encapsulating bras are more suitable for this, decreasing the amount of displacement at higher levels of exercise intensity in relation to the compression bras (Scurr *et al*., 2011). A considerable amount of additional factors which have not been taken into consideration for this study or studies in the past still play a role in how the breast tissue responds to movement and how much support is offered by the bra. Fabric elasticity, breast stiffness and other body characteristics all play a role (Haake & Scurr, 2010; Zhou, Yu & Ng, 2011). This leaves room for more research to be done by manufacturing companies.

To describe the motion of breast tissue is a difficult task as it is made up of a deformable body of tissue. The breast tissue contains adipose tissue, ligament, and mammary glands which have viscous damping hyper-elastic behaviours. There is a further challenge when measuring the kinematics of the breast as it must be measured in relation to the thorax which influences the breast tissues pattern of movement with thoracic rotation (Zhou *et al*, 2012). It is important to note that not all research done in this field have used the same reference positions. Most commonly used are segment optimization, position and orientation. The segment orientation is assumed to be ridged and any change in soft tissue is residual error (Mills, Loveridge, Milligan, Risius & Scurr, 2014). Reference positions also vary and are not anatomical landmarks and so are difficult to replicate and are subject to tester variability (Zhou *et al.*, 2011).

Newton's 1st law states that a body will remain at rest or constant motion unless an external force is applied. If we apply this law to the kinematics of the breast we see that when running and in the Two-Step Star Jump test, breast tissue is displaced upward with the initiation of movement. As the body changes direction to a downward motion the breast tissue continues upward, as the breast tissue loses acceleration and starts to displace in a downward motion the body has already started to move in the opposite direction once more. This results in a 'bounce' or rather superior/inferior displacement of the breast tissue (Bridgman *et al*., 2010).

To reduce the momentum of the breast tissue women are encouraged to wear a sports bra. By wearing the correct fitting bra an external force is applied to each breast mound. The better the support the less deviation will be seen in the breast tissue in relation to the trunk and from the body's harmonic motion. Harmonic motion describes the relationship between objects which oscillate (up and down), ideally we want to see the breast tissue and trunk move as one. This however can never be the case as external forces are acting on the breast tissue, mediolateral, anteroposterior, and superior-inferior. Thus we have to change momentum. Previous studies have suggested that breast pain is felt with the stretching of the supporting structures, skin and fascia of the breast and can occur with repeated loading of the breast with physical activity. This could result in breast sag (Scurr *et al*., 2011). This is an additional avenue to be explored to establish the mechanical demands of the breast tissue, whether tension on the skin and fascia cause the breast to extend beyond the anatomical reference point when loaded through gravity or if it is limited to external forces (Mills *et al*., 2014).

The following hypotheses of this study were proven to be correct: Breast displacement was significantly reduced in all directions during a standard incremental treadmill test when wearing the HIU bra compared to a no bra condition. The second hypothesis was also proven to be correct as the HIU bra showed significant reduction in breast displacement during treadmill running compared to the three different Shock Absorber support level bras as well as with participants Own bra. Other studied have suggested that the most significant movement in breast displacement is the vertical displacement of the breast (Bridgman, 2010; Milligan *et al*., 2011). The HIU bra proved once more that in the vertical plane of movement (Z-Plane) it measured statistically significant values in the reduction of breast tissue displacement in comparison to the no bra condition, comparison with three different Shock Absorber support level bras and participants Own bra.

The hypothesis stating there is a correlation between breast displacement and treadmill speed (as the speed increases so will breast displacement up to a certain level) was accepted at the speed of 10km/h. At this speed the breast tissue appeared to plateau and reach a steady state of displacement. However more research is needed to fully understand the mechanical demands of the breast tissue and whether they are influenced equally by external and internal forces (Scurr *et al*., 2011). The final hypothesis was aimed at establishing bra/breast comfort and support ratings during treadmill running in the HIU bra compared to the other conditions. The HIU bra scored the highest regarding comfort and reducing breast pain. However it is important to note that the High impact support level bra and Medium impact support bra also scored well in these areas. This is a relevant finding since not all activity requires the maximum support and these bras may be used in light activity where the forces experienced on the breast tissue are limited.

All Hypotheses were thus proven to be correct. Breast displacement was significantly reduced in all planes of movement while performing a standard incremental treadmill test as well as in the performing of the Two-Step Star Jump test while participants were wearing the HIU bra in comparison to the Control and three other conditions.

CHAPTER FIVE: SUMMARY, RESULTS & LIMITATIONS

5.1 SUMMARY

It has been established that the correct amount of support and the correct fit in women's sports bras is required to prevent mastalgia and long term complications and sag in breast tissue. This study was aimed at testing the capabilities of a new sports bra on the market namely, the HIU Shock Absorber bra. Thirty female participants were recruited and evaluated for the study. Cup sizes of the participants ranged from B-C, all participants were required to run on the treadmill at different incremental stages and perform a Two-Step Star Jump test to establish breast displacement. This was done during six conditions; Control (no bra), Own bra, Low impact support, Medium impact support, High impact support level bra and the HIU bra.

In this study we looked at six different conditions and there influence on the breast tissue. The aim was to establish if the new HIU bra design from Shock Absorber was superior to previous Shock Absorber bra models with varying levels of support. Whether displacement of the breast tissue could be decreased by limiting the amount of external forces acting on the breast tissue and thus changing momentum, while performing a standard incremental treadmill test and Two-Step Star Jump test.

Four sets of data were collected: 1.) Displacement of the right breast in the X (lateral) Plane, Y (anteroposterior) Plane, and Z (vertical or superior-inferior) Plane. 2.) The percent reduction of the right breast in each plane with a Control (no bra condition). 3.) The percent reduction of the right breast in each plane with the participants Own bra and four Shock Absorber bras with varying levels of support including the HIU bra. 4.) The Residual displacement and percent reduction of breast displacement when performing the Two-Step Star Jump test.

Non-parametric statistics were used as a result of atypical distribution of the data. This showed that only statistically significant differences ($p<0.05$) in the reduction of Residual breast displacement in both the standard incremental treadmill test and Two-Step Star Jump test was found when participant performed the tests wearing the HIU bra.

In conclusion it can be said that the new HIU bra for Shock Absorber met all requirement of the proposed hypotheses and indeed decreased breast displacement in the X, Y, and Z-Planes as well as Residual displacement. Percent reduction was significantly decreased ($p<0.05$) in comparison to the other conditions and demonstrates the ability of the HIU bra to limit the amount of external force acting on the breast tissue in complex whole body movements. This is in line with other studies which have been completed, demonstrating the benefit of wearing a well fitted encapsulating sports bra in reducing breast displacement and discomfort while participating in physical activity (Bowles *et al.*, 2011).

Perceptual feedback also indicated that participants felt comfortable in the HIU bra, with the perception of a decreased feeling of breast pain. Dislikes in the design were aimed at ill-fitting straps, to tight or too loose as well as the fit around the bust. It would be beneficial for manufacturers to take a closer look at strap design and elasticity of the fabric (Bowles *et al.*, 2011).

Thus it appears as if the HIU bra is suitable for high impact sport for women who require breast support. In activities that are less strenuous lower levels of support are adequate.

5.2 LIMITATIONS

Possible limitations for this study include a small sample size, the exclusion of inactive females and those that were unfamiliar with treadmill running. The study also makes use of a convenient sample which includes only South African women form cup size B-C.

Using a convenience sample limited our study by ethnicity and by breast size. We were only able to research women who were smaller busted and therefore may be less inclined to need as much breast support as they would experience less external forces and torque on the breast tissue compared to bigger busted women who were excluded from the study. Our data therefore may be limited in its range of maximum displacement that can be experienced by the breast tissue as compared to bigger busted women. Majority of the participant were Caucasian as a result of the smaller cup size B-C as they are naturally smaller busted than African women.

The exclusion of inactive females poses the same limitation, as more active women are more inclined to be smaller busted as they have lower levels of body fat percentage and fat store. This also affected the number of participants as we had to turn away candidates who were unaccustomed to running on a treadmill. These factors contributed to our smaller sample size which again limits the diversity of the research by ethnicity and breast size.

We were only able to research a group of seventeen female participants who were similar in age and breast size with similar medical history and upbringing. This population group is therefore not a very accurate representation of the wider female population in the area.

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APPENDICES

APPENDIX A: Informed consent

INFORMED CONSENT

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Department of Biokinetics,
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The kinematics of supported and unsupported breast displacement during standard incremental treadmill activity and Two-Step Star Jumping

Purpose
The aim of this study is to investigate the biomechanical effects of a new sports bra in comparison to other bras while walking/running on a treadmill.

Procedures
If you volunteer for this study and fit the selection criteria you will assist us in the objective described above. You will be assessed on three occasions and each assessment will take approximately 20 minutes. For the first assessment, your body mass, height and bra size will be determined as well as your suitability for participation in the study. The second and third assessment will consist of a biomechanical evaluation (motion capture). You will be required to walk/ run on the treadmill wearing various bras as well as no bra. Markers will be placed on the breasts and / or bras you will be wearing. Please note only female researchers will be used.

Benefits
You will benefit by receiving feedback on your bra size as well as advice on suitable bras for sports and physical activity.

Risks and discomforts
The risks involved are not foreseen to be any greater than that associated with exercising.

Responsibilities of the participant
You are responsible for fully disclosing all information requested in terms of injuries or illness experienced in last 6 months, and for the prompt reporting of any problems that may occur during the study. Also, all testing procedures should be performed to the best of your ability to allow valid conclusions to be constructed.

Confidentiality
The information that is obtained from this study in all tests will be treated as private and confidential. It will not be released or reported to any person other than the researchers involved in the study and yourself. However, the information may be used for statistical analysis or scientific purposes with your details remaining anonymous.

Enquiries
You are encouraged to ask any questions about the testing you might undergo and the procedures you will need to follow. If you have any concerns or questions, please ask us for further explanations.

FREEDOM OF CONSENT

I, ____ (full name of subject), have read the abovementioned description, and have been informed of the procedures, requirements, benefits and risks of participating in this research project.

I therefore declare that I willingly cooperate in this project at my own risk, and will not withhold any information that may be of importance to the researchers or for my own safety. I am aware that I participate voluntarily, and may withdraw from this project at any time if I so wish, without any cost to myself.

I hereby also grant the researchers permission to use my results for publication and/or presentation purposes, with my anonymity being ensured.

______________________ ______________________
Signature of subject Signature of researcher

______________________ ______________________
Signature of witness Date

Contact telephone number: _______________________________

E-mail address: ____

APPENDIX B: Indemnity form

Institute for Sports Research
University of Pretoria

100 1908 - 2008 UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA

INDEMNITY/ASSUMPTION OF RISK

I, the undersigned, hereby declare and agree as follows towards the Institute for Sport Research (hereinafter referred to as the 'ISR') at the University of Pretoria (hereinafter referred to as the 'UNIVERSITY')

1. In wish to participate in a prescribed exercise, training, evaluation, rehabilitation or gymnasium program (hereinafter the 'program'). I realise that my participation in such program involves risks of injury, including, but not limited to musculoskeletal injury, abnormal blood pressure, fainting, irregular, fast or slow heart rhythm, and in rare instances heart attack, stroke or death. I realise that there are many other risks of injury, including serious disabling injuries that may arise due to my participation in such program, and that it is not possible to specifically list each and every individual injury risk. However, knowing the material risks and appreciating, knowing and reasonably anticipating that other injuries and even death are a possibility, I hereby expressly assume all risks of injury, loss or damage, and even risk of death, which could occur by reason of my participation in the program. I abide by and submit myself herewith to the applicable conditions and regulations of the ISR at the UNIVERSITY, which shall include but not be limited to the conditions and regulations pertaining to the ISR and/or the UNIVERSITY's facilities and services such as training, evaluation, rehabilitation, gymnasium programmes and general use of the ISR and/or the UNIVERISITY's facilities and equipment.

2. I herewith indemnify and hold harmless the UNIVERSITY against all claims instituted by myself, my spouse, my children or other dependents, resulting from any loss, damage, injury or death, which I may sustain as a result of the use of the ISR and/or the UNIVERSITY's facilities and/or participation in the program,

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whether or not such loss, damage, injury or death is caused throughout the negligence of the UNIVERSITY.I am aware of the fact that my health may currently constitute a potential risk to my participation in the program which I am about to commence. I understand that my participation in any program at the ISR shall be at my own risk and this indemnity includes all the employees and subcontractors of the ISR and the UNIVERISITY.

3. I have had an opportunity to ask questions. Any questions I have asked have been answered to my complete satisfaction. I subjectively understand the risks of my participation in the program, and knowing and appreciating these risks I voluntarily choose to participate, assuming all risks of injury or even death due to my participation.

4. The information that is obtained during consultation and exercise testing will be treated as confidential and the ISR has undertaken not to release or reveal such information to any person, except my referring physician, without my prior consent. However, the information obtained may be used for statistical analysis or scientific purposes with my right of privacy being retained. Additionally all medical records will be archived for a period of 15 years as prescribed by the Health Professions Council of South Africa.

5. I hereby declare that all information regarding my health and which may cause a health risk have been disclosed to the UNIVERSITY and accept the clause regarding the use and archiving of my medical records

6. I have read the abovementioned information before signing below and fully understand the contents, meaning and impact thereof.

Name of Prospective Patient: ______________________________

Signed at _________________ on this _____ day of __________________ 20_____

Contact Number: ______________________________

Witness: _____________________________________

Comments:

____

____

Biokineticist: _____________________________

Date: ___________________________________

APPENDIX C: Pre-participation screening form

PRE-PARTICPATION SCREENING

100
1908 - 2008

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

1. **General Information**
   - Name: ______________________________
   - Date of Birth: ______________________________
   - Age: ______________________________
   - Contact Number: ______________________________
   - Email Address: ______________________________

2. **Medical Conditions**
   Are you currently suffering from any injury or illness?
   ____

3. **Injury History**
   Please specify any previous injuries you have had (last 2 years)?
   ____

4. **Medications**
   Are you taking any medication currently? (Please specify medication and dosage)
   ____

5. **Current Training Regime**
   What is your current training regime?
   - *Mode:* ________________________
   - *Duration:* ________________________
   - *Days per Week:* ________________________

6. **Have you ever had breast surgery?** Yes / No
7. **Are you currently pregnant or were you pregnant in the last year?** Yes / No

8. **Other**
   In your opinion is there any reason why you think you should not participate in this study or something that the researchers should be aware of before you participate in this study?
   ____

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APPENDIX D: Advert

VOLUNTEERS REQUIRED FOR A RESEARCH PROJECT ON SPORTS BRAS

GET INVOLVED IN RESEARCH

Females between the ages of 18 and 39 years that are recreationally active (exercise for at least 30 minutes, twice a week) may volunteer for the study. You will be assessed on 3 occasions and assessments will take approximately 20 minutes. Your bra size will be determined and you will be required to walk/run on a treadmill wearing various bras.

FREE OFFER

- Volunteer for free bra fitting
- Free advice on appropriate bra selection for physical activity
- Free Sports bra

AGE: 18-39
Cup size: B-DD
Fitness level: 30mins, twice a week
When: 3 Assessments

20-24 August 2012

Qualified FEMALE biokineticists will conduct the assessments. The data collected will be used for a University of Pretoria research project. Results will be anonymous and confidential and will be used for research purposes only.

For more information please contact:

Lauzanne Booysen
012 420 6033
Lauzanne.booysen@up.ac.za

Sasha Padoa
012 420 6033
Sasha.padoa@up.ac.za

APPENDIX E: Letter from DB Apparel SA

DBApparel South Africa
101 Lawley Street Jacobs 4052
P O Box 12359 Jacobs 4026
Kwazulu-Natal South Africa
[illegible]

10 May 2012

Dr Kim Nolte

Department of Biokinetics, Sport and Leisure Sciences

University of Pretoria

DBA South Africa would like to participate in research of our Shock Absorber sport underwear apparel in South Africa similar to studies conducted in the UK (research brief provided).

DBA would supply all underwear including base product to be tested against.

The quote provided is within our budget requirements and the next step will be to obtain ethics approval and then finalise the research in terms of timings, actual samples needed etc.

Looking forward to hearing from you soon.

Kind regards

Vanessa Schreyer
Marketing Manager

DBApparel South Africa (Pty) Ltd.
Registration Number 2005/040042/07
DIRECTORS: JA MacDonald(Managing), C Paul

Playtex THE ONE AND ONLY wonderbra BEAR

APPENDIX F: Ethical approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Research Ethics Committee

11 June 2012

Dear Dr Nolte,

Project:	**The effect of breast support on the kinematics of the breast during the running gait cycle**
Researcher:	**K Nolte**
Department:	**Biokinetics, Sport and Leisure Science**
Reference:	**Staff research**

I have pleasure in informing you that the Registrar has formally given **approval** for the above study to be conducted at the University of Pretoria. Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should your actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely

p.p. Prof John Sharp
Chair: Research Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: john.sharp@up.ac.za

APPENDIX G: Perceptual evaluation

Questionnaire

Participant Number: ……………………………….. Testing Date:…………………………….

Bra:………………………………………………………………………………………….…….

After each breast support condition please rate:

1) How comfortable your breasts felt during the trial? (Please circle)

0 1 2 3 4 5 6 7 8 9 10 Very Uncomfortable … Very Comfortable		Office use only

2) The intensity of breast pain felt during the trial? (Please circle)

Moderate 0 1 2 3 4 5 6 7 8 9 10 No Pain … Excruciating Pain		Office use only

3) How comfortable did the bra feel during the trial (if applicable)? (Please circle)

Moderate 0 1 2 3 4 5 6 7 8 9 10 Very Unsupportive … Very Supportive		Office use only

4) How supportive did the bra feel when you were completing the trial (if applicable)? (Please circle)

						Moderate						
	0	1	2	3	4	5	6	7	8	9	10	
Very Uncomfortable												Would wear

Office use only

5) What was the fit of the bra like (if applicable)? (Please circle)

						Moderate						
	0	1	2	3	4	5	6	7	8	9	10	
Very Poor Fit												Very Good Fit

Office use only

6) Were there any design features in this bra which you particularly liked/ disliked? (E.g. the way it looked, straps, fabric etc.)

LIKES:	
DISKLIKES:	

7) Do you have any suggestions for improvements to the product?

8) Please add any further comments: