Bilateral differences in anthropometric measurements and isokinetic strength variables of female university level netball players

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DECLARATION

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The following is a statement of the co-authors confirming their individual role in this study and giving permission that the manuscripts may form part of this dissertation.

I declare that I have approved the above mentioned manuscripts, and that my role in this study, as indicated above is representative of my actual contribution. I hereby give my consent that the above mentioned manuscripts may be published as part of the Masters dissertation of Mrs. Kyra Duvenage.

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ABSTRACT

Bilateral differences in anthropometric measurements and isokinetic strength variables of female university level netball players

Unilateral movements refer to a movement performed by a single limb, whereas bilateral movements are performed with both limbs. The literature review conducted for this study, indicated that netball players favour unilateral movements during most throwing and jumping actions. These unilateral movements may lead to anthropometric and strength bilateral differences in the upper and lower body between the dominant (D) and non-dominant (ND) limbs of netball players.

Anthropometric profiles are important when considering success in the performance of sport, and provide coaches and sport scientists with needed information about the current state of the athlete's body composition (during the different phases of training). From research in sporting codes that predominantly use unilateral movements, it can be noted that an adaptation to certain anthropometrical measurements occurs. The repeated use of the D limb in unilateral sporting codes is a major factor in asymmetrical development and therefore the assessment of bilateral differences between limbs is of great importance. The performance of netball players is affected by muscular strength and power, which are important characteristics of their general physical condition. In bilateral muscle strength measurements, it is recommended that the strength of muscle groups that are compared should not differ greatly (>10-15%) between the D and ND limbs, since this may have an undesirable effect on performance. Bilateral differences are a phenomenon that deserves attention because it demonstrates that the type of movement used (bilaterally or unilaterally) can have an effect on the anthropometric and isokinetic muscle strength.

The first objective of this study was to determine if there were significant bilateral differences in the anthropometric measurement between the D and ND limbs in the upper and lower parts of the body. Secondly, to determine if there were significant bilateral differences in isokinetic strength variables between the upper and lower D and ND limbs of the body. To obtain these objectives, forty four female university level netball players (age: 20.02±1.39 years; stature: 175.68±7.17cm; and body mass: 72.50±8.82kg) of the North-West University in South Africa were recruited to participate in this study. Descriptive statistics (averages, standard deviations, minimum and maximum values) for each of the relevant variables was calculated to determine the anthropometric profiles and Isokinetic variables of the players. Technical error of measurement and Confidence Interval (90%) was calculated for the anthropometrical measurements. A

dependent t-test for statistical significance ($p \leq 0.05$) was done for the total group for the different variables (D and ND of the upper and lower limbs) regarding the bilateral differences. Effect size was calculated for the total group and Cohen's effect size to determine practical significance. To support the first objective of this study, results obtained by the measurements of the full anthropometric profiles taken on the D and ND limbs were compared. The biceps skinfold (-17.93±28.85%) had the largest level of asymmetry and showed a statistical and practical significance difference of $p=0.00$ ($d=0.34$).

To support the second objective of this study, results obtained from the knee and shoulder isokinetic strength tests revealed that there were no statistical or practical significant differences between the D and ND isokinetic knee strength ($p>0.48$; $d<0.1$). In contrast to the previous mentioned, some shoulder measurements (shoulder flexion/extension) showed a statistical ($p<0.02$) and practical ($d>0.28$) significant difference between the D and ND side. The shoulder extensor variable showed a stronger statistical and practical significant difference ($p=0.00$; $d=0.44$) than the shoulder flexors ($p=0.01$; $d=0.29$), even though the shoulder flexion-extension ratio showed no statistical or practical significant difference between the D and ND side ($p=0.55$; $d=0.10$).

These findings are evidence that netball players tend to develop marginal bilateral differences between D and ND limbs in response to the demands of the sport and their unilateral movements. Thus, the researcher concludes that university level netball players showed statistical and practical significant differences between the D and ND side in the upperbody.

Key terms: Anthropometry, bilateral differences, dominance, isokinetic strength, knee extension/flexion, netball players, shoulder flexion/extension.

OPSOMMING

Bilaterale verskille in antropometriese metings en isokinetiese kragveranderlikes in universiteitsvlak-netbalspeelsters

Unilaterale bewegings verwys na bewegings wat deur ’n enkele ledemaat uitgevoer word, teenoor bilaterale bewegings wat met albei ledemate uitgevoer word. Die literatuuroorsig dui aan dat netbalspelers voorkeur verleen aan unilaterale bewegings gedurende die meeste gooi- en spring-aksies. Hierdie unilaterale bewegings mag lei tot antropometiese en krag bilaterale verskille in die bo- en onderlyf tussen die dominante (D) en nie-dominante (ND) ledemate van netbalspelers.

Antropometriese profiele is belangrik wanneer sukses in sport in ag geneem word en gee aan afrigters en sportwetenskaplikes die nodige inligting oor die huidige stand van die atleet se liggaamsamestelling (gedurende die verskillende fases van oefening). Volgens navorsing in sportkodes wat hoofsaaklik unilaterale bewegings gebruik, vind ’n adaptasie van sekere antropometiese metings plaas. Die herhaalde gebruik van die D ledemaat in unilaterale sportkodes is een van die hooffaktore in asimmetriese ontwikkeling en daarom is die meting van bilaterale verskille tussen ledemate baie belangrik. Die prestasie van netbalspelers word beïnvloed deur spier- en eksplosiewekrag, wat belangrike kenmerke is van die algemene fisieke toestand. In metings van bilaterale spier krag word aanbeveel dat die krag van die spiergroepe wat vergelyk word, nie ’n beduidendeverskil (>10-15%) moet toon tussen die D en ND ledemate nie, aangesien dit ’n ongewenste uitwerking op prestasie mag hê. Bilaterale verskille is ’n verskynsel wat aandag verdien, aangesien dit toon dat die tipe beweging wat gebruik word (bilateraal of unilateraal) ’n uitwerking kan hê op die antropometriese en isokinetese spierkrag.

Die eerste doelwit van hierdie studie was om vas te stel of daar betekenisvolle bilaterale verskille in die antropometriese metings tussen die D en ND ledemate in die bo- en onderlyf is. Tweedens was dit om vas te stel of daar betekenisvolle bilaterale verskille in isokinetiese kragveranderlikes tussen die D en ND ledemate was (bo- een onderlyf). Om hierdie doelstellings te bereik, is universiteitsvlak-netbalspelers genader. Vier-en-veertig netbalspeelsters (ouderdom: 20.2±1.4 jaar; lengte: 175.7±7.2 cm en liggaamsmassa: 72.5±8.8 kg) van die ’n universiteit in die Noordwes provinsie in Suid-Afrika het aan die studie deelgeneem. Beskrywende statistiek (gemiddelde, standaard afwyking, minimum, en maksimum waarde) vir elke relevante waarde was bereken om die antropometriese en isokinetiese profiel te bepaal van die spelers. Tegniese meetingsfout en Vertrouensinterval (90%) was bereken vir die antropometriese metings, waarna ’n afhanklike t-toets vir statistiese betekenisvolheid ($p \leq 0.05$) bereken is vir die totale groep vir die verskillende meings (D en ND van die boonste- en onderste ledemate). Effek grootte was bepaal vir die totale

groep en Cohen's effek grootte vir praktiese betekenisvolheid. Om die eerste doelwit van hierdie studie te bereik, is 'n vergelyking getref is deur die meting van die volle antropometiese profiele van die D en ND ledemate vergelyk. Daar is gevind dat die biseps-velvou (-17.93±28.85%) die grootste asimmetrie getoon het, wat die statistiese en praktiese betekenisvolle verskil van p=0.00 (d=0.34) na vore bring.

Om die tweede doelwit van hierdie studie te bereik, het resultate wat van die knie- en skouer-isokinetiese kragtoetse verkry is, getoon dat daar geen statisties of prakties betekenisvolle verskil tussen die D en ND isokinetiese kniekrag (p>0.48; d<0.1) was nie. In teenstelling met hierdie bevindings het skouermetings (skouerfleksie-extensie) in die bo-lyf 'n statisties (p<0.02) en prakties (d>0.28) betekenisvolle verskil tussen die D en die ND kant getoon. Die skouer-ekstensor veranderlike het 'n groter statisties en prakties betekenisvolle verskil (p=0.00; d=0.44) getoon teenoor die skouerfleksors (p=0.01; d=0.29), alhoewel die skouerfleksie-ekstensie verhouding geen statisties of prakties betekenisvolle verskil tussen die D en ND kante (p=0.55; d=0.10) getoon het nie.

Hierdie bevindings bewys dat netbalspelers neig na die ontwikkeling van bepaalde bilaterale verskille tussen die D en ND ledemate, in reaksie op die vereistes van die sport en hulle unilaterale bewegings. Die navorser kom tot die gevolgtrekking dat universiteitsvlak-netbalspelers statistiese en praktiese betekenisvolle verskille tussen die D en ND kante in die bo-lyf toon.

Sleutelterme: Antropometrie, bilaterale verskille, dominansie, isokinetiese krag, kniefleksie/ekstensie, netbalspelers, skouerfleksie/ekstensie

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LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
%	Percentage
<	Smaller than
>	Greater than
±	Plus-minus
≤	Smaller than and equal to
≥	Greater than and equal to
°	Degree
/	Per
AG:AN	Agonist – Antagonist ratio
cm	Centimetre
CI	Confident Interval
d	Cohen's d-value
D	Dominant
ES	Effect size
et al	Et alia / and others
ER:IR	External-Internal ratio
EXT:FXT	Extention-flextion ratio
FXT:EXT	Flexion-extension ratio
H:Q	Hamstring:Quadriceps ratio
ISAK	International Society of Advancement of Kinanthropometry
kg	Kilogram
m	Meter
MD	Mean difference
mm	Millimetre
ND	Non-dominant
Nm	Newton-meter
p	Statistical significance
PT	Peak torque
sec	Second(s)

CHAPTER 1 – INTRODUCTION

1.1 INTRODUCTION

The continual investigation of the development of sport performance enhancement has identified that players in certain court sports such as netball may be subject to bilateral muscle development (Hopper *et al.,* 1992:102). Cheung *et al*. (2012:66) stated that with long-term training, bilateral strength development may be present in some sports where unilateral movements are predominant. Performance will also be influenced by several factors, such as body size, training status and muscle fibre type (Camic *et al.*, 2010:2362; Hoffman, 2006:4; Housh *et al.,* 1995:261), therefore appropriate body composition and strength development will improve performance in sport (Bale & Hunt, 1986:18; Čižmek *et al*., 2010:123; Swinton *et al.,* 2014:1847; Tomkinson & Olds, 2000:549).

1.2 PROBLEM STATEMENT

Most daily living activities and different sport codes demand unilateral movements (McCurdy & Conner, 2003:50). Therefore, unilateral exercises may be more beneficial than bilateral exercise based on adherence to the concept of training specificity (Sale, 1988:140). The changes in anthropometric characteristics may be a sign of an adaptive body process, and it would therefore be wise for coaches to control the bilateral development of athletes, as the differences may be a sign of excessive single-sided arm overload (Cuk *et al.,* 2012:113). However, researchers have up to now attempted to investigate the strength and anthropometry (Bale & Hunt, 1986:17; Ferreira & Spamer, 2010:61; Hopper, 1997:198; Hopper *et al.,* 1995:217; Soh *et al*., 2009:280; Venter *et al.,* 2005:5) of netball players, but have not made any attempt to investigate the bilateral comparisons in anthropometric measurements and isokinetic strength variables of university level netball players.

Unilateral movements in netball may vary and mostly depend on dominant (D) and non-dominant (ND) limbs (Hopper *et al.*, 1992:103). Factors influencing unilateral movements in netball include the type of pass (one and two-handed), height of the pass, the direction of the movement when intercepting the ball and whether the D or ND limb is used (Otago, 2004:89). The two-handed chest pass is often associated with netball players (Gamble, 2011:10), but in a study done by Hopper *et al*. (1992:103), it was found that players predominantly use the right-handed pass (48.7%), followed by the two-handed chest pass (40.2%), whereas the left-handed pass was rarely used (5.9%). Hopper *et al.* (1992:102-103) found that during a netball game right-foot landings where performed more frequently (32.4%), followed by left-foot landings (26.1%), whereas landing on both feet appeared to occur even less often (23.9%). When executing an

attacking move to receive the ball, the players approached the ball with a leap or hop (29.4%), one foot planted on the ground (25%), or with a jump (24.7%) (Hopper *et al.*, 1992:102).

Excessive weight is usually placed on the D leg, while the ND leg is protected from deceleration of the body during movement in unilateral tasks (Pappas & Carpes, 2012:90). An isokinetic dynamometer can be used to compare the strength values of the D and ND limbs (Dervišević & Hadžić, 2012:294). It is an objective apparatus to measure peak torque in Newton metre (Nm) (Carvalho *et al.,* 2012:2883), which is reliable for knee extension-flexion (r=0.83–0.93) and shoulder extension-flexion (r=0.78–0.95) (Perrin, 1986:322).

Considering similar court-based sports with unilateral movements, it is necessary to understand the effect of these movements on the bilateral development of the body. Research done on basketball players found no statistical significant differences (p=-0.699) between right and left leg isokinetic strength values (Berg *et al.,* 1985:63). Berg *et al.* (1985:62) found that the left leg was 6% (at 60°/sec) stronger than the right leg, and the left shoulder was 4.9% (at 60°/sec) stronger than the right shoulder in the extension-flexion test (dominance was not mentioned). Knapik *et al*. (1991:77) stated that if the differences between the right and left leg were greater than 15%, a negative effect on performance which may lead to possible injuries. Cheung *et al.* (2012:68) found that most court players (volleyball and basketball) had less than 15% discrepancy in isokinetic strength between their D and ND lower limbs. Consistent with the results of the previous study, a small difference (>15%) in peak torque values between right and left limbs across four joints (knee, shoulder, elbow and ankle) was also found (Berg *et al.,* 1985:60). In contrast to these findings, Hadžic *et al.* (2013:861) found a statistical significant difference (p=0.01) in favour of the D limb in quadriceps concentric isokinetic strength values in senior male basketball players. The findings of Markou and Vagenas (2006:74) confirm the notion of a statistical significance (p=0.013) in bilateral differences of the D and ND shoulder joint in male volleyball players. Based on this data, the peak torque (force) differences in shoulder strength of volleyball players can only be attributed to the fact that the D side develops a systematic superiority in overall muscle strength over the years (Markou & Vagenas, 2006:77). Literature also shows that other factors (gender, age, physical activity and anthropometry) can affect performance results of the isokinetic strength tests (Keating & Matyas, 1996:882).

Anthropometry refers to measurements of the human body and the proportion of body weight that is either fat relative or consists of lean tissue (Hoffman, 2006:88). These anthropometry measurements include; stature, body mass, skinfolds, girths, lengths and breadths (Norton *et al*, 2000:33). Anthropometry provides coaches and sport specialists with imperative information with regards to the current body composition during different training phases. Research has shown that previous anthropometric studies on netball players only focused on body fat percentage

(Ferreira & Spamer, 2010:61; Soh *et al*., 2009:280; Venter *et al.,* 2005:5) and the somatotype (Bale & Hunt, 1986:17; Hopper, 1997:198; Hopper *et al.,* 1995:217). A study done by Tomkinson *et al*. (2003:204) focused on the anthropometrical bilateral values of male basketball and soccer players. These researchers found no significant differences for any derived variables between the D and the ND side (upper and lower limbs) of the players. No studies were found on the comparison of bilateral differences in netball players regarding anthropometric profiling.

Due to limited data on bilateral differences in anthropometric variables and isokinetic strength in netball players, the following research questions arise: Firstly, are there significant bilateral differences in anthropometric measurements between D and ND limbs (upper and lower body) of university level netball players? Secondly, are there bilateral differences in isokinetic strength variables between D and ND limbs (upper and lower body)?

Answers to the above-mentioned research questions would be of importance to coaches and sport scientists and could provide a guideline for these professionals regarding scientifically formulated exercise programmes for preventing bilateral differences among netball players.

1.3 OBJECTIVES

The objectives of this study were to determine:

- Bilateral differences in anthropometric measurements between D and ND limbs (upper and lower body) of university level netball players
- Bilateral differences in isokinetic strength variables between D and ND limbs (upper and lower body) of university level netball players.

1.4 HYPOTHESES

This study was based on the following hypotheses:

- Statistical significant differences between the D and ND limbs (upper and lower body) will occur, with the D limb presenting smaller anthropometric values for skinfold measurements and larger girths and bone breadths measurements for university level netball players.
- Statistical significant differences between the D and ND limbs (upper and lower body) will occur and the D limbs will present greater peak torque values, and better agonist/antagonist muscle ratio percentages for university level netball players.

1.5 STRUCTURE OF DISSERTATION

Chapter 1: Introduction

Chapter 2: Literature review: "BILATERAL DIFFERENCES IN ANTHROPOMETRIC MEASUREMENTS AND ISOKINETIC STRENGTH VARIABLES OF NETBALL AND OTHER UNILATERAL SPORT CODES." . This chapter is not a complete literature study but merely a literature review of the most important literature that will from basis of the article's literature.

Chapter 3: Article 1: "UPPER AND LOWER BILATERAL DIFFERENCES IN ANTHROPOMETRIC MEASUREMENTS OF UNIVERSITY LEVEL NETBALL PLAYERS." (To be submitted for publication in the *South African Journal of Research in Sport, Physical Education and Recreation)*. Although not according to the guidelines of the journal, the tables will be included within the text and will be numbered according to the chapters to ease the reading of the article. Furthermore, the line spacing and the margins of the article will be the same as Chapter 1, 2 & 5.

Chapter 4: Article 2: "BILATERAL DIFFERENCES IN UPPER AND LOWER BODY ISOKINETIC STRENGTH OF UNIVERSITY LEVEL NETBALL PLAYERS." (To be submitted for publication in the *South African Journal of Research in Sport, Physical Education and Recreation*). Although not according to the guidelines of the journal, the tables will be included within the text and will be numbered according to the chapters to ease the reading of the article. Furthermore, the line spacing and the margins of the article will be the same as Chapter 1, 2 & 5.

Chapter 5: Summary, conclusion, limitations, recommendations and future research.

REFERENCES

Bale, P. & Hunt, S. 1986. The physique, body composition and training variables of elite and good netball players in relation to playing position. *Australian journal of science and medicine in sport,* 18(4): 16-19.

Berg, K., Blanke, D. & Miller, M. 1985. Muscular fitness profile of female college basketball players. *The journal of orthopaedic and sports physical therapy,* 7(2): 59–64.

Camic, C.L., Housh, T.J., Weir, J.P., Zuniga, J.M., Hendrix, C.R., Mielke, M., Johnson, G.O., Housh, D.J. & Schmidt, R.T. 2010. Influences of body size variables on age-related increases in isokinetic peak torque in young wrestlers. *Journal of strength conditioning research,* 24(9): 2358-2365.

Carvalho, H.M., Coelho-e-Silva, M., Valente-dos-Santos, J., Gonçalves, R.S., Phillippaerts, R. & Malina, R. 2012. Scaling lower-limb isokinetic strength for biological maturation and body size in adolescent basketball players. *European journal of applied physiology,* 112(8): 2881-2889.

Cheung, R.T.H., Smith, A.W. & Wong, D.P. 2012. H:Q ratios and bilateral leg strength in college field and court sports players. *Journal of human kinetics,* 33(Jun): 63-71.

Čižmek, A., Ohnjec, K., Vučetić, V. & Gruić, I. 2010. Morphological differences of elite Croatian female handball players according to their game position. *Hrvatski sportskomedicinski vjesnik,* 25(2): 122-127.

Cuk, I., Pajek, M., Jakse, B., Pajek, J. & Pecek, M. 2012. Morphologic bilateral differences of top level gymnasts. *International journal of morphology,* 30(1): 110-114.

Dervišević, E. & Hadžić, V. 2012. Quadriceps and hamstrings strength in team sports: Basketball, football and volleyball. *Isokinetics and exercise science,* 20(4): 293-300.

Ferreira, M.A. & Spamer, E.J. 2010. Biomechanical, anthropometrical and physical profile of elite university netball players and the relationship to muscularskeletal injuries. *South African journal of research in sport, physical education and recreation,* 32(1): 57-67.

Gamble, P. 2011. Physical preparation for netball – Part 1: Needs analysis and injury epidemiology. *UK strength and conditioning association,* 22: 10-15.

Hadžic, V., Erčulj, F., Bračič, M. & Dervišević, E. 2013. Bilateral concentric and eccentric isokinetic strength evaluation of quadriceps and hamstrings in basketball players. *Collegium antropologicum,* 37(3): 859-865.

Hoffman, J. 2006. Fitness and health assessment. *Norms for fitness, performance and health.* Human Kinetics.

Hopper, D. 1997. Somatotype in high performance female netball players may influence player position and the incidence of lower limb and back injuries. *British journal of sport medicine,* 31(3): 197-199.

Hopper, D., Hopper, J. & Elliot, B. 1995. Do selected kinanthropometric and performance variables predict injuries in female netball players? *Journal of sport sciences,* 13(3): 213-222.

Hopper, D., Lo, S.K., Kirkham, C. & Elliot, B. 1992. Landing patterns in netball: Analysis of an international game. *British journal of sport medicine,* 26(2): 101–106.

Housh, T.J., Stout, J.R., Weir, J.P., Weir, L.L., Housh, D.J., Johnson, G.O. & Evans, S.A. 1995. Relationship of age and muscle mass to peak torque in high school wrestlers. *Research quarterly for exercise and sport,* 66(3): 256-261.

Keating, J.L. & Matyas, T.A. 1996. The influence of subject and test design on dynamometric measurements of extremity muscles. *Physical therapy,* 76(8): 866-889.

Knapik, J.J., Bauman, C.L., Jones, B.H., Harris, J.M. & Vaughan, L. 1991. Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *American journal of sports medicine,* 19(1): 76-81.

Markou, S. & Vagenas, G. 2006. Multivariate isokinetic asymmetry of the knee and shoulder in elite volleyball players. *European journal of sport science,* 6(1): 71-80.

McCurdy, K. & Conner, C. 2003. Unilateral support resistance training incorporating the hip and knee. *Strength conditioning journal,* 25(2): 45–51.

Norton, K., Whittingham, N., Carter, L., Kerr, D., Gore, C. & Marfell-Jones, M. 2000. Measurement techniques in anthropometry. (*In* Norton, K.L. & Olds, T.S., *eds*. Anthropometrica: a textbook of body measurement for sports and health courses. Marrickville, NSW: Southwood Press. P. 25-75).

Otago, L. 2004. Kinetic analysis of landing in netball: Is a footwork rule change required to decrease ACL injuries. *Journal of science and medicine in sport,* 7(1): 85–95.

Pappas, E. & Carpes, F.P. 2012. Lower extremity kinematic asymmetry in male and female athletes performing jump-landing tasks. *Journal of science and medicine in sport,* 15(1): 87-92.

Perrin D.H. 1986. Reliability of isokinetic measures. *Athletic training,* 21: 319-326.

Sale, D. 1988. Neural adaptation to resistance training. *Medicine and science in sports exercise,* 20(5): 135–145.

Soh, K.G., Soh, K.L., Ruby, H., Sofian, O.F.M., Aminuddin, Y. & Marjohan, J. 2009. Comparison of physical profile of Malaysian basketball and netball players by playing position. *African journal for physical, health education, recreation and dance,* 5(2): 278-284.

Swinton, P., Lloyd, R., Keogh, J., Agouris, I. & Stewart, A. 2014. Regression models of sprint, vertical jump, and change of direction performance. *Journal of strength and conditioning research,* 28(7): 1839-1848.

Tomkinson, G.R. & Olds, T.S. 2000. Physiological correlates of bilateral symmetry in humans. *International journal of sports medicine*, 21(8): 545-550.

Tomkinson, G.R., Popovic, N. & Martin, M. 2003. Bilateral symmetry and the competitive standard attained in elite and sub-elite sport. *Journal of sport science,* 21(3): 201-211.

Venter R.E., Fourie L., Ferreira S. & Terblanche E. 2005. Physical and physiological profiles of Boland netball players. *South African journal of sport medicine.* 17(2):3-7.

CHAPTER 2 – LITERATURE REVIEW
BILATERAL DIFFERENCES IN ANTHROPOMETRIC MEASUREMENTS AND ISOKINETIC STRENGTH VARIABLES OF NETBALL AND OTHER UNILATERAL SPORT CODES

2.1 INTRODUCTION

The first netball game was played in 1895 in England at Madame Ostenburg's College (INF, 2013:3). Netball, a fast and skilful game that originated from basketball (Shakespear & Caldow, 2009:xi), continued to grow in the first half of the 20th century, with the game being played by all British Commonwealth countries (INF, 2013:3; Shakespear & Caldow, 2009:xi). No formal rules for netball existed prior to 1957, however, in 1960 representatives from Australia, England, New Zealand, South Africa and West India congregated in Sri Lanka to establish a committee named *The International Federation of Women's Basketball and Netball* (Shakespear & Caldow, 2009:xi). Standardised rules were discussed and finalised at this inaugural meeting and this committee decided to present the *World Championship Tournament* every four years, starting from 1963 (INF, 2013:3; Shakespear & Caldow, 2009:xi). Netball developed into a renowned sport and in 1995 the *International Olympic Committee* welcomed netball to the 1998 Commonwealth Games (Shakespear & Caldow, 2009:xi).

Netball is a court-based sport predominantly played by females (Cormack *et al*., 2014:283), although it has become more popular among males (INF, 2013:3). This game is played between two opposing teams of seven players each, competing to gain possession of the ball (INF, 2013:3; Shakespear & Caldow, 2009:xi). During play, the team in possession of the ball attempts to move the ball towards its own goal post, where the goal shooters are positioned. Limited movements on court are allowed once a player is in possession of the ball and a pass must be executed within three seconds, according to the rules (Cormack *et al*., 2014:283; Woodlands, 2006:11). The aim of the team in possession of the ball is to shoot a goal, while the opposing team uses defence strategies to prevent the goal from being scored and attempts to gain possession of the ball. The team that scores most goals succeeds in winning the netball match (Cormack *et al*., 2014:283; INF, 2013:3; Shakespear & Caldow, 2009:xi).

Netball is a dynamic and physically demanding sport that often requires players to perform diverse movements such as repetitive jump-landing actions, repeated short runs, quick starts and stops, as well as sudden changes in direction (Chang *et al*., 2013:187; Terblanche & Venter, 2009:136). Bloomfield *et al.* (2007:1093) found that court-based sports such as basketball and netball have

unique physical elements, which include multi-directional speed, linear speed, agility with acceleration, lateral movements, deceleration and backwards running.

These above-mentioned movements and elements are vitally important for netball players in all playing positions (Terblanche & Venter, 2009:136). Movement strategies in netball vary and are carried out predominantly from a unilateral platform, which includes movements such as change of direction, jumping, running, hopping, and throwing (Fort-Vanmeerhaeghe *et al.*, 2016:135; McCurdy & Conner, 2003:45). Unilateral movements are described as a weight-bearing movement mainly supported by one limb (McCurdy & Conner, 2003:45). These unilateral movement patterns in any given support base have an effect on the body's morphological and strength profiles.

For the purpose of this literature review, research studies included different sporting codes (Javelin, Hockey, Football and Athletics) pertaining unilateral movements due to the limited research done on netball and other court-based sports. Inadequate recent studies required some research to be included prior to 2008. Studies were included if the participation was on club, provincial, university and elite level. Research done on male and female subjects (from adolescent onwards) was included to investigate the bilateral difference development of active and inactive test subjects.

2.2 UNILATERAL MOVEMENTS

As previously mentioned, when executing a movement from a unilateral platform, it is referred to as a weight-bearing movement supported by one limb, whereas bilateral movements are performed with the weight evenly distributed between both limbs (McCurdy & Conner, 2003:45). Bilateral movements ensure a larger base support, which increases stability and decreases the impact forces on the weight-bearing limbs (Hewit *et al*., 2012b:512).

Unilateral movements are predominantly used in court-based sport such as netball and basketball. Jumping from, or landing on one leg during a rebound, and passing the ball with one hand are seen as unilateral movements (McCurdy & Conner, 2003:48). During a jump movement, the dominant (D) leg is preferred for landing, when weight is mainly transferred to the D leg. This decreases the impact on the non-dominant (ND) leg (Pappas & Carpes, 2012:90). During the throwing phase, forces are produced as the body's weight is transferred from the back leg to the front leg, and most of the weight is supported by one leg (McCurdy & Conner, 2003:48). Factors that have an effect on unilateral movements during play include the type or height of the pass (straight, loop, or bounce) and the direction of the movement when intercepting the ball (Otago, 2004:89). Lavipour (2009:52) found that during two netball matches, netball players tended to perform double the number of jumps from a unilateral base support (67%) than from a bilateral

base support (33%). During different match situations, players approached the ball by using unilateral base support movements such as a leap (landing on the foot opposite the take-off limb), hop (landing on the take-off limb), leap and hop combined (29.4%), one foot planted on the ground (25%), or with a jump (confined to elevation rather than a stride; 24.7%) (Hopper *et al*., 1992:102). These explosive movements from a unilateral base support vary and are influenced by the dominance (side preference) of the netball player (Hopper *et al*., 1992:103).

Dominance is known as the tendency among humans to use one side of the body selectively above the other in voluntary movements, which can be observed between people who present the selective use of a hand or foot associated with motor skills (Serrien *et al.*, 2006:165). Lateral dominance refers to the functional specialization of either the left or right brain hemispheres (Hebbal & Mysorekar, 2006:164). The two brain hemispheres function differently and this results in the selective use of one limb (preferred side) for motor skills under voluntary control, also known as limb dominance (Velotta *et al*., 2011:1037). Carpes *et al*. (2010:137) mentioned that research shows 90% of humans have a right-hand preference, in contrast to only 25-40% right-leg preference in the lower extremity movements. This can be explained by the fact that the lower limbs' movements requires more brain activation compared to those of the upper limbs. Lower limb dominance is associated with the task required to be done (manipulative or body stabilisation) (Velotta *et al*., 2011:1037). Velotta *et al*., (2011:1038) suggest that lower limb dominance is related to the type of task the subject is asked to perform. If the task is manipulative in nature (kicking a ball, or taking a step forward), the majority of subjects (80-90%) will rely on the right leg as the preferred or D limb, but when performing stabilisation of the whole body the preference shifts to the left leg. When stabilisation skills are exercised, the opposite lower limb is used during the dynamic counter-balance and the right lower limb performs better at manipulative skills. This is the reason for the change in preferred limb when using different skills (Sadeghi *et al*., 2000:40).

Netball's stepping rule is structured, based on the landing foot. When landing on both feet simultaneously (bilateral landing), the player may take a first step with either foot as opposed to being limited to the ground contact foot when initially landing on one foot (unilateral landing) (Hewit *et al*., 2012b:512). In the late 1990s, a study on the analysis of different movement patterns of netball players in an international match between New Zealand and Australia found that the landing movements during the netball match reflected that right-foot landings were performed more frequently (32.4%), whereas left-foot landings (26.1%) and landings on both feet (23.9%) (two-footed symmetrical landings) appeared to be less frequently used. Bilateral (two-footed asymmetrical) landings were barely used (13.6%) during netball matches; however, the side preference of the players was not recorded (Hopper *et al*. 1992:102). Although this study gave valuable information on the movement, the game has changed in nature over the years. Netball

players who participate at regional and national level show better performance on the D lower limb in an unanticipated 180°-turn task (Maulder, 2013:127). This may be because individuals can learn tasks and skills more successfully with their D limb than the ND limb (Davidson & Wolpret, 2003:235).

Regarding throwing or passing of the ball, the D limb is preferred during one-handed passes such as overhead passes and shoulder passes (Gamble, 2011:10; Woodlands 2006:19); however, the two-handed chest pass is also a favourite during a netball match (Gamble, 2011:10). According to the study of Hopper *et al*. (1992:102), the shoulder pass was more frequently used in a match (the ball is passed in a horizontal direction to another player) (73.1%), where the right hand was predominantly used (48.7%), followed by both hands (40.2%). The left hand was rarely used (5.9%) during throwing or passing. When catching the ball, players most often use both hands (94.1%) and the area on the body where they catch the ball is mostly between the head and chest area (62.4%). Research shows that playing position has an influence on the placing of the ball. In the study of Hopper *et al*. (1992:103), one- and two-handed passes (47.7%) were equally favoured for mid-court players, whereas defence players preferred the one-handed pass with the right hand (81.3%).

From the above-mentioned literature, it is clear that netball players favour unilateral movement patterns during throwing, passing, catching, jumping and landing. Unilateral movement patterns may lead to the possibility of strength asymmetry in the upper and lower bodies of these players (Hewit *et al*., 2012a:238: Maulder, 2013:127). Factors that contribute to asymmetry between limbs include dominance, coordination, current muscle imbalances and an injury history (Hewit *et al*., 2012a:238) as well as unilateral movements (Blackburn & Knüsel, 2006:379; Cheung *et al.*, 2012:66; Hart *et al.*, 2014:161).

2.3 BILATERAL DIFFERENCES/ASYMMETRY

The human body has a growth trajectory to maintain symmetry in most traits; however, it is hard to obtain perfect symmetry (Manning & Pickup, 1998:208). Asymmetry is defined as the lack of equality or equivalence between parts or the lack of symmetry (Oxford English Dictionary, 2017), which refers to the difference between the two sides of the body, and is seen as normal (Krischan & Kanchan, 2016:578). In this review, the researcher considers that the term bilateral differences refers to a difference between the bilateral limbs, whereas asymmetry also indicates that there is a remarkable difference between the bilateral limbs.

The continuous evaluation of sport performance enhancement has recognised that players in certain court sports, such as netball, may be exposed to bilateral muscle development through training (Hopper *et al.*, 1992:102). Bilateral difference/asymmetry is one of the features that play

a very significant part in sports training, and is determined by factors including the unique nature of any given sports discipline (Brown *et al*., 2014:918). Studies found a positive correlation between performance and bilateral asymmetry. However, it was found that athletes with more symmetrical development tend to perform better (Manning & Pickup, 1998:207; Trivers *et al*., 2014:8). Taking into account long-term training effects, bilateral strength development may occur more frequently in sports where unilateral movements are predominant (Cheung *et al.*, 2012:66).

A substantial amount of research indicated the presence of asymmetry in athletes from different sporting codes and concluded that the asymmetry occurred as a result of different movement patterns used in the specific sporting code (Berg *et al*., 1985:60; Blackburn & Knüsel, 2006:379; Brown *et al.,* 2014:918; Carpes *et al*., 2010:138; Cheung *et al*., 2012:66; Hart *et al.*, 2014:161; Knapik *et al*., 1991:77; Kong & Burns, 2010:15; Kruger *et al*., 2005:50; Krzykała & Leszczyński, 2015:384; Lanshammer & Ribom, 2011:78; Markou & Vagenas, 2006:73; Pappas & Carpes, 2012:90; Phillips *et al.*, 2000:151; Radjo *et al*., 2013:725; Rynkiewicz *et al.,* 2013:49; Tomkinson *et al*., 2003:205). Asymmetric adaptation in the lower limbs can be the result of specific demands such as jumping and change of direction (Fort-Vanmeerhaeghe *et al*., 2015:321). Unilateral tasks such as (anthropometric measurements and isokinetic assessments) are often used to assess asymmetry and the result is expressed in percentages. Various studies found correlations between the percentage of asymmetry among the D and ND limbs in unilateral and bilateral movements (Blackburn & Knüsel, 2006:379; Cheung *et al.*, 2012:66).

Bilateral difference/asymmetric adaptation of anthropometrical and strength measurements is found in sporting codes that predominantly use movements from a unilateral base support and where limb dominance has an influence on the level of asymmetry (Blackburn & Knüsel, 2006:378; Hart *et al.*, 2014:161). As mentioned previously, different asymmetries were found in various unilateral sporting codes. Two components that were taken into consideration for this literature review on asymmetry were anthropometrical and isokinetic strength differences of participants in sporting codes with predominantly unilateral-based movements.

2.3.1 Bilateral differences/asymmetry in anthropometry

Anthropometry refers to the measurements of the human body as well as the proportion of body weight that is either fat-related or consists of lean tissue (Hoffman, 2006:88). Anthropometric profiles are important when considering success in performance of sport, and provide coaches and sport professionals with needed information about the current state of the athlete's body composition (during the different phases of training) (Bale & Hunt, 1986:18; Čižmek *et al*., 2010:123). Previous anthropometric studies on netball players focused on the percentage of body fat (Ferreira & Spamer, 2010:61; Soh *et al.,* 2009:280; Venter *et al.,* 2005:5) and the somatotype

(Bale & Hunt, 1986:17; Hopper, 1997:198) but limited research could be found on bilateral differences that led to asymmetry in anthropometric measurement of netball players.

Because of limited research on bilateral differences, a brief overview of anthropometric studies pertaining to netball players will be discussed. A study that Ferreira and Spamer (2010:61 conducted on elite female university-level netball players (u/19 A and B team) in the North West Province had an average stature of 174.6cm, body mass of 68.2kg and percentage body fat of 26.61% (no standard deviation between the players was calculated. These findings are similar to the findings of Venter *et al.* (2005:5) on provincial and national level netball players in South Africa (stature 172.6±7.5cm, body mass 66.8±9.1kg and percentage body fat 25.0±4.3%), and Soh *et al.* (2009:280) on national Malaysian netball players (stature of 170.80±4.16cm, body mass of 64.44±7.46kg and percentage body fat 24.50±5.13%).

Another component to consider with in the anthropometric field is somatotyping of a sportsperson. Carter and Heath (1990:199) mentioned that the level of competition and performance has an influence on the somatotype profiling of a sportsperson. The somatotype of an athlete describes the built with grading of the athlete's adiposity, musculoskeletal robustness and linearity (Carter & Heath, 1990:453). Bale and Hunt (1986:17) stated that the average somatotype of elite young United Kingdom netball players are predominantly meso-endomorph (4-3.6-3.3) with an average stature of 170.8±6.1cm, body mass of 64.5±3.5kg, and percentage body fat of 24.5±3.9%. This is similar to the study of Hopper (1997:199), where the average somatotype of Australian netball players were identified as being a meso-endomorph (3.6–3.5–2.9). From these two studies, it is clear that netball players lean towards the meso-endomorph profile, which indicates that they tend to have relatively moderate subcutaneous fat cover, as well as moderate musculoskeletal development (Carter & Stewart, 2012:70). Limited research has been done on the anthropometric profiles of netball players and little to no focused research has been undertaken on the asymmetry or bilateral differences in anthropometrical data of D and ND limbs in unilateral sport or in netball per se.

Research in sporting codes that predominantly use movements from unilateral base support, noted that adaptation to certain anthropometrical measurements occurs. Upper limb dominance (stronger hand when performing certain tasks such as throwing a ball) has a positive link to the hypertrophy of the distal humerus of inactive female subjects. The epicondyle breadth accurately reflects handiness (dominance) in 68% of cases, where the D epicondyle breadth is larger than that of the ND side (Blackburn & Knüsel, 2006:378). This study's results showed statistical significant bilateral differences ($p<0.001$) between left- and right-handed test subjects, and therefore appeared to reflect a positive relationship regarding the direction of asymmetry and an individual's D hand (Blackburn & Knüsel, 2006:378). In football players, the lower limbs showed

a positive correlation (r=0.31-0.41) between kicking performance and lean mass values (Hart *et al.*, 2014:161). A positive correlation was found between the lean mass of the thigh segment and kicking accuracy (Kicking: r=-0.43 to -0.59; Support: r=-0.53 to -0.59). Accurate kickers had smaller lean mass asymmetry (SI=-1% to 1%) than inaccurate kickers (SI=0% to 3%), with statistical significant differences between accurate and inaccurate kickers (p=0.003 to 0.029). Inaccurate kickers showed lower lean mass values in their support limb relative to their kicking limb. This low lean mass (4%) for the inaccurate kickers correlates with their weaker support leg (8%), which was noted by the imbalance of the unilateral strength (Hart *et al*., 2014:161). In contrast with these findings, Carpes *et al.* (2010:141) failed to find a correlation between functional asymmetry and limb dominance for the lower limbs and therefore could not fully address any relationship between asymmetries and performance. On this point, it is not clear whether sport dominating in unilateral movement patterns causes an increase in bilateral difference in the anthropometrical measurements between the D and ND legs. In the 1980s, Sale (1988:140) commented that the answer to this previous mentioned question would help with training specificity and sport conditioning. Further research is needed to investigate the effect of unilateral movement patterns on the bilateral differences of anthropometric measurements.

Sporting codes, other than netball, which use predominantly unilateral movements differ significantly between the D and ND limbs concerning different anthropometrical measurements (Blackburn & Knüsel, 2006:378; Kruger *et al*., 2005:50; Krzykała & Leszczyński, 2015:384). In previous research done on anthropometrical asymmetry, Blackburn and Knüsel (2006:378) found statistical significant differences in the epicondylar humerus breadths of active and inactive individuals (p<0.001). Asymmetry was also found in the relaxed upper arm girth (p<0.05), forearm girth (p<0.001) and half chest girth (p<0.001) with the larger values on the D side of elite male javelin throwers (Kruger *et al.*, 2005:50). The study done on female Polish hockey players found asymmetry in lean muscle mass for the upper limbs (p<0.0007) and trunk (p<0.0006), as well as fat mass (measured in grams) for the upper limbs (p<0.0008) (Krzykala & Leszcynski, 2015:384). It is clear from the above-mentioned studies that statistical significant bilateral differences (p<0.001) occurred for various anthropometrical variables of various sporting codes predominantly using unilateral movements.

This is contradictory to other studies that showed no significant differences between the D and ND sides (Markou & Vagenas, 2006:73; Radjo *et al*., 2013:725; Rynkiewicz *et al*., 2013:49; Tomkinson *et al*., 2003:208). Tomkinson *et al.* (2003:208) found no statistical bilateral differences (p<0.50) in any of the anthropometrical measurements (full protocol except for measurements not part of a bilateral pair e.g. chest and waist girths) of male soccer and basketball players competing at professional and semi-professional league level. These findings are in correspondence with the study of Markou and Vagenes (2006:73), which found that Greek male volleyball players

showed no significant bilateral differences in leg length ($p<0.214$) (Markou & Vagenas, 2006:73). Similar findings were found to those of Radjo *et al*. (2013:725), who found no significant bilateral differences in the lower leg length ($p<0.487$), thigh length ($p<0.232$), lower leg girth ($p<0.227$) and thigh girth ($p<0.030$) of cadet and club-level basketball players. Lastly, Rynkiewicz *et al*. (2013:49) found no significant bilateral differences between the D and ND sides for muscle mass in the upper and lower limbs ($p<0.62$ and $p<0.95$) of junior cadet tennis players.

Table 2.1 summarises these previously discussed indices of anthropometrical bilateral asymmetry among different sport codes. It can be observed from the studies mentioned that significant bilateral difference is more prominent for upper body anthropometrical measurements than lower body anthropometrical measurements (Blackburn & Knüsel, 2006:378; Kruger *et al*., 2005:50*;* Krzykała & Leszczyński, 2015:383). Specifically, skinfold measurements exhibited no significant difference of asymmetry from any of the studies mentioned in table 2.1.

Muscular adaptation is a result of sport participation and therefore to assess muscular adaptations and bilateral differences in sports with unilateral movement can add value to the above-mentioned review of anthropometrical data.

Table 2-1: Summary of descriptive statistics from indices of anthropometrical asymmetry among athletes in different sport codes.

Source	Anthropometrical measurements	Subject information	Results				Signif (p)
Kruger *et al.,* 2005	12 Anthropometrical indices	19 international male javelin throwers	**Measurements**	**D**	**ND**	**Asymmetry**	
			Relaxed upper arm girth	35.2 ± 1.4*	34.6 ± 1.7*	1.7 ± 2.9%	*p < 0.05
			Forearm girth	30.6 ±1.9**	29.4 ± 1.6**	4.0 ± 3.8%	**p< 0.001
			Half chest girth	55.9 ± 3.2**	52.8 ± 3.2**	5.7 ±7.6%	**p< 0.001
			Acromial radial length	37.3 ± 2.7*	36 ± 1.4*	3.5 ± 6.3%	
			Midstalion – dactilion length	21.8 ± 1.3*	21.1 ± 0.8*	3.3 ± 6.3%	
Krzykała & Leszczyński, 2015	Bone mineral density (BMD), lean mass (LM) and fat mass (FM)	17 female Polish field hockey players National level (age 21.01 ± 3.83)	**Measurements**	**Left side**	**Right Side**		
			BMD lower extremity (g/cm^2)	1.39 ± 0.072	1.36 ± 0.065		p = 0.0132
			BMD trunk (g/cm^2)	1.03 ± 0.059	1.00 ± 0.049		p = 0.0033
			LM upper extremity (g)	2352.12± 302.53	2206.12 ± 259.83		p = 0.0007
			LM trunk (g)	10478.18 ± 811.69	10080.00 ± 721.21		p = 0.0006
			FM upper extremity (g)	762.65 ± 233.719	715.71 ± 229.075		p = 0.0008
			FM trunk	3739.12 ± 1347.111	3599.00 ± 1286.904		p = 0.007
Markou & Vagenas, 2006	Leg length	24 elite Greek male volleyball players	**Measurements**	**Left leg (cm)**	**Right leg (cm)**		
			Leg length	98.85 ± 3.62	98.67 ± 3.71		p = 0.214
Radjo *et al*., 2013	Lower leg and thigh length and lower leg and thigh girth	68 cadet and club-level basketball players (age 16.61 ± 0.49 years). Gender was not specified	**Measurements**	**Left leg (cm)**	**Right leg (cm)**		
			Lower leg length	46.11 ± 3.13	46.14 ± 3.14		p = 0.487
			Thigh length	45.04 ± 3.68	44.96 ± 3.71		p = 0.232
			Lower leg girth	38.62 ± 3.21	38.54 ± 3.19		p = 0.227
			Thigh girth	57.11 ± 5.39	57.29 ± 5.44		p = 0.030
Rynkiewicz *et al.,* 2013	Muscle mass of upper and lower limbs	16 Polish junior cadet tennis players (age 15.19 ± 1.05)	**Limb**	**D**	**ND**	**Asymmetry**	
			Upper limb	3.47 ± 0.76	3.33 ± 0.75	4.06 ± 1.82	p = 0.62
			Lower limb	9.68 ± 1.71	9.72 ± 1.67	-0.41 ± 1.02	p = 0.95

Source	Anthropometrical measurements	Subject information	Results				Signif (p)
Tomkinson *et al.*, 2003	Full anthropometrical profile for bilateral trades	26 elite and sub-elite Australian male basketball players and 26 elite and sub-elite Australian soccer players (age = 25.1 ± 3.5 years)	**Measurements**	**(R + L)/2 Mean ± s_x**	**Spearman rank order**	**(R-L) Mean ± s_x**	
			Triceps skinfold (mm)	8.1 ± 0.36	0.33	0.41 ± 0.11	p < 0.50
			Relaxed upper arm girth (cm)	31.1 ± 0.36	0.18	0.35 ± 0.10	
			Flexed upper arm girth (cm)	33.5 ± 0.38	0.10	0.45 ± 0.11	
			Forearm girth (cm)	28.4 ± 0.25	-0.09	0.40 ± 0.07	
			Trochanterion height (cm)	97.4 ± 0.96	-0.11	-0.43 ± 0.11	
			Humerus breadths (cm)	7.16 ± 0.06	0.03	0.09 ± 0.02	

Signif – significance, BMD = Bone mass density, LM = Lean mass, FM = Fat mass, g = gram; g/cm^2 = gram per square centimetre, mm = millimetres, cm = centimetre, R = Right, L = Left, D = Dominant, ND = Non-dominant
Statistical significance: *p < 0.05; **p< 0.001

2.3.2 Bilateral differences/asymmetry in strength

The repeated use of the D limb in unilateral sporting codes is a major factor in asymmetrical development and therefore the assessment of bilateral differences between limbs is of great importance (Botton *et al.*, 2013:164). Better understanding of the bilateral difference phenomena and the effect thereof on performance will enable a more specific approach to training (Carpes *et al*., 2010:138).

The performance of netball players are affected by muscular strength and is an important characteristic of their general physical conditioning (Radjo, 2013:727; Woodlands 2006:196). Power is also an important characteristic of muscles strength during court-based sport and is vital during dynamic movements in all planes (Montgomery *et al*. 2010:83). Strength can be defined as the ability of a muscle to produce force and is measured in newton (N) (Humac/Norm™, 2014:107), whereas power is the ability of a muscle to produce force over a period of time and is expressed in watts (W). Therefore, power can be defined as the work per unit over time and is dependent on the strength of a muscle and the velocity of the moving limb (Sapega & Drillings, 1983:7). Peak torque (PT) is the most common variable representing the strength of a muscle group during a movement and can be standardised to body weight (Olmo *et al*., 2006:283). Peak torque is calculated by the force applied around an axis of rotation and is expressed as: Torque (Nm) = Force (Newton) × Distance (metre), where the distance is the perpendicular distance from the input of force to the centre of rotation (Carvalho *et al*., 2012:2883; Humac/Norm™, 2014:107). Thus, PT is the maximum force production during a movement at any given point (Humac/Norm™, 2014:107).

Lower body strength improves short-term, high-intensity activities and is beneficial for netball players during acceleration on court (Chad & Steele, 1991:8). Players must also be able to produce a strong take-off from a standing position or to elevate and catch high passes (Shakespear & Caldow 2009:173, Woodlands, 2006:11). The quadriceps and hamstring muscles are important prime lower body movers in locomotor actions such as sprints, rapid change of direction, jumping and landing (Xaverova *et al*., 2015:257). Factors in the game of netball, which influence the landing patterns, are pace patterns, receipt and passing of the ball, direction of movement towards the ball and the player's position (Hopper *et al*., 1992:101). In a previous study, Hopper *et al.* (1992:101) stated that netball players mainly rely on their D lower limb when approaching the ball, but they would rather choose the ND lower limb when landing after catching the ball. This is contradictory to the findings of Pappas and Carpes (2012:90) which states that during a jump movement the D lower limb is preferred during the landing phase. As previously mentioned, the basic lower body movements of netball include jumping or landing from a unilateral or bilateral base of support (Lavipour, 2009:98). The game analysis study of Lavipour (2009:52)

found that during two games between New Zealand teams, netball players tended to perform double the number of unilateral jump-landings than bilateral jump-landings (approximately 67% vs 33%). The researcher also found that the landing phase reflected equal unilateral and bilateral landings (47% vs 53%) for the vertical jumps, but for the forward and lateral jumps unilateral landings were preferably used (78% and 68% respectively).

Due to unilateral movements, the asymmetric nature of the shoulder movement in overhead throwing sport codes, causes imbalances between the D and ND shoulder strength, as well as imbalances between external and internal shoulder rotator muscles (Hadzic *et al*., 2014:338). During the kinematic analysis of a shoulder pass, most of the muscles activated during the pass are the muscles of the shoulder, arm and forearm (Hetherington *et al*., 2009:250). The torque required during the acceleration part of the shoulder pass is mainly provided by the concentric contraction of shoulder flexors (Hetherington *et al*., 2009:250). The primary movers during a throwing action are known to be the teres major and latissimus dorsi muscles for the shoulder extension movement, and the anterior deltoid and the upper fibres of the pectoralis major for the shoulder flexion movement (Copeland, 1993:222; Cybex Norm™, 1996:E-2)

To assess the performance of a moving muscle, different types of dynamometers are used (Kovačević *et al.*, 2012:49; Land & Gordon, 2011:231). Isokinetic dynamometers are objective, reliable (knee extension/flexion r=0.83-0.993, shoulder extension/flexion r=0.78-0.95), and reproducible (Callaghan *et al.*, 2000:682; Dervišević & Hadžić, 2012:293; Duarte *et al*., 2018:7; Miller *et al*., 2004:229; Perrin, 1986;332). Criticism of isokinetic dynamometers is that they are not functional (Augustsson & Thomee, 2000:167) and are very expensive equipment to buy or use (Toonstra & Mattacola, 2013:3). Evaluations done on an isokinetic dynamometer can be used to assess the strength (PT) and power (W) of a muscle or a group of muscles to compare the absolute and relative bilateral values between the D and ND sides (Dervišević & Hadžić, 2012:294). To compare a participant's PT to normative data, it is important to investigate the torque-to-bodyweight ratio of the participant (Humac/Norm™ 2014:4-5). This assessment can also determine the existence of bilateral strength differences in the percentage ratios of the agonist (AG) and antagonist (AN) muscles (Bamaç *et al*., 2008:182; Humac/Norm™ 2014:1-8).

It is advisable that bilateral muscle strength measurements should not indicate a great difference between the muscle groups (Xaverova *et al*., 2015:263). Bilateral strength differences of the upper and lower body may have an undesirable effect on performance and differences higher than 10-15% among the D and ND limb in muscle strength need immediate attention (Fort-Vanmeerhaeghe *et al.*, 2016:141; Hewit *et al.*, 2012a:242; Knapik *et al.*, 1991:77). In intermitted sports, court and field players developed different muscular strength profiles due to long-term training effects (Cheung *et al*., 2012:66).

Limited studies have been done on the isokinetic strength profiles of university-level netball players; therefore other similar court-based sports will also form part of this study. In one of a few studies done on netball players, Malaysian netball players showed that the overall leg strength for the right and left knee extension at 60°/sec was 159.46±26.33Nm and 149.96±26.83Nm respectively, whereas the right and left knee flexion at 60°/sec was 89.67±17.28Nm and 89.39±13.88Nm respectively (Soh *et al*., 2006:42). It is clear from the data (although it was not investigated) that in the knee extension muscles, the bilateral difference was 5.96% between the right and left knees but less than 1% for the knee flexors. In view of this data it is therefore imperative to gain more knowledge regarding isokinetic bilateral strength differences of university-level netball players.

Several studies investigated the effect of bilateral strength differences on sport performance (Hart *et al.*, 2014:161; Siqueira *et al*., 2002:21). When considering the dominance factor, Siqueira *et al*. (2002:22) found that non-athletes show a higher significant bilateral difference (p<0.009) in hamstring muscles between D and ND limbs than athletes competing in running and jumping events. In the study of Hart *et al.*, (2014:161), researchers found moderate practical significance (d=0.3-0.6*)* and a moderate positive correlation (r=0.25-0.40) with the kicking accuracy in the bilateral and unilateral strength of the kicking and support limbs of football players. The study's results showed that there was a large percentage of bilateral difference (7%-14%) for inaccurate kickers compared to accurate kickers.

Numerous studies have shown a significant bilateral difference between D and ND isokinetic knee strength (Kong & Burns, 2010; Lanshammer & Ribom, 2011:78; Phillips *et al*., 2000:151; Radjo *et al*., 2013:725). Female subjects showed higher concentric quadriceps PT values of 5.6%-7.7% on the D side, and for the hamstring muscles, the difference between the D and ND sides was small, ranging between 1.1% and 2.3% (Phillips *et al*., 2000:151). Lanshammer and Ribom's (2011:78) research mentioned considerable bilateral differences in quadriceps (p<0.009) and hamstring (p<0.001) muscle strength between the D and ND lower limb in female subjects, irrespective of the physical activity (ball sports, aerobics, strength training etc.) in which they participated. The participants displayed 8.6% weaker hamstring muscle strength (p<0.001) and 5.3% stronger quadriceps muscle strength (p<0.009) of the D leg (Lanshammer & Ribom, 2011:78). Furthermore, a study of Radjo *et al*., (2013:725) on cadet basketball players found a statistical significant difference between quadriceps muscles (p=0.019) and hamstring muscles (p=0.000) of the left and right leg, all in favour of the right leg (dominance of players was not recorded). These studies are in correspondence with the findings of Kong and Burns (2010:15) that found significant differences (p=0.006) between the D and ND hamstring for recreationally active males and females, were the D limb had the greatest values. These studies clearly indicate

that there was a significant bilateral difference in the lower limbs, where the D limb registered better results.

Findings on the upper limbs achieved by Berg *et al.* (1985:61) revealed that university level female basketball players' shoulder isokinetic strength for flexion/extension at 60º/sec was 33.4±5.0Nm and 41.65±6.5Nm for the left shoulder and 34.5±4.6Nm and 44.5±4.9Nm for the right shoulder respectively, with a deficit of 3% for the shoulder flexors and 6.9% for the shoulder extensor muscles (dominance was not specified in this study). Limited research has been done on the shoulder flexion/extension isokinetic test; therefore, it is important to investigate other shoulder isokinetic tests to gain knowledge about the differences between D and ND shoulder strength. Markou and Vagenas, (2006:78) advocate that female volleyball court players are inclined to show muscle strength asymmetry between the D and ND shoulder during the isokinetic external and internal rotation (ER/IR) test at a velocity of 60º/sec. Peak torque differences (difference of 4%, $p<0.004$) for internal rotation between the D and ND sides in shoulder strength of elite Greek male volleyball players may be attributed to the fact that the D side develops systematically more in strength over the years compared to the ND side (Markou & Vagenas, 2006:77).

Bilateral differences exist not only in muscle strength values, but also between the percentage ratios of the AG and AN muscle groups at a joint of the D and ND limbs. Agonist to antagonist muscle ratios (AG:AN) of athletes participating in different sporting codes at similar competing levels may depend on the specific demands of the sport (Kabacinski *et al.*, 2018:8). To understand the AG:AN value better, Humac/Norm™ (2014:4-6) described the concept as follows: the opposing muscle group torque ratio indicates the weaker muscle group torque as a percentage (%) of the stronger muscle group torque. During the knee extension/flexion test, the knee flexion PT is indicated as a percentage of the knee extension PT. For example, if a test subject produced a PT in flexion of 141Nm and a PT in extension of 256Nm on the D side, then the subject had an opposing muscle group ratio of 55% on that side (141/256=0.55x100=55%), thus indicating that on the dominant side, at PT, the test subject's flexors were 55% as strong as his extensors. With regard to the hamstring and quadriceps muscles, some studies have reported AG:AN values ranging from 50% to 80% (Cheung *et al*., 2012:68; Hewett *et al*., 2008:455; Kong & Burns, 2010:15), with the general acceptance for AG:AN at 60% (Coombs & Carbutt, 2002:57), depending on muscle group and testing velocity, which seems not to differ between genders or sporting codes (Rosene *et al*., 2001:382). Kabacinski *et al.* (2018:6) found that female volleyball players showed a higher ($p<0.05$) hamstring:quadricep ratio (H:Q) (13.8% left leg and 14.4% right leg higher) than basketball players. Lanshammer and Ribom (2011:77) found that the D legs' H:Q was 46±0.08% and the ND legs' H:Q was 53±0.09% ($p>0.001$) at a testing velocity of 90º/sec, which indicates that for the D lower limb, the participants showed stronger quadriceps muscles strength (5.3%) and weaker hamstring muscle strength (8.6%) than in the ND leg. Kong and Burns

(2010:15) stated that recreationally active male and female participants' H:Q increased when angular velocity (60°/sec, 180°/sec and 300°/sec) was increased ($p<0.001$) in the D leg. This resulted in a higher percentage ratio with regard to all angular velocities. Kong and Burns (2010:15) concluded that the H:Q differences, with a higher ratio on the D leg, can be attributed to the stronger hamstring muscle in the D leg, while the quadriceps muscle was mostly similar for both legs, and explained that this difference is due to the different training background of these participants (Kong & Burns, 2010:15). Throughout the literature, it can be noted that there is a notion of different isokinetic strength asymmetries for active and inactive subjects, as well as for athletes in different sporting codes. It is also noted that contradiction in the literature exists and limited research has been done on the netball sporting code involving university-level players.

Table 2.2 summarises the indices of isokinetic strength asymmetry among different sporting codes. It is evident from the listed studies that there are statistical significant differences between the D and ND limbs for peak torque and muscle ratios between AG and AN muscles (Berg *et al*., 1985; Kong & Burns, 2010:15; Lanshammer & Ribom, 2011:78; Markou & Vagenas, 2006:73-74; Phillips *et al.*, 2000:151; Radjo *et al*., 2013:725).

Table 2-2: Summary of descriptive statistics from indices in isokinetic strength bilateral differences among different test subjects and athletes of different sport codes.

Study	Limb dominance	Subjects	Isokinetic dynamometer	Test Protocol	Statistics used	Results
Berg *et al.,* 1985	Did not specify (Half of the subjects test first the right limb and other half the left limb)	13 female basketball players (age = 20.42 ± 1.21)	Cybex II	Knee, shoulder, elbow flexion/extension at 60 º/sec - 300º/sec velocity Ankle plantar/dorsiflexion at 30 º/sec - 150º/sec velocity	Mean of values with standard deviation	a) Difference of 0.4 – 6.9% in PT for extensors at all 4 joints. b) Difference of 0.2 – 12.4% in PT for flexors at all 4 joints. c) L knee 6% > R knee EX:FL d) L shoulder 4.9% > R shoulder EX:FL
Cheung *et al.,* 2012	The D leg was determined as the leg used to kick a ball	40 male collegiate athletes from soccer (n=23), basketball (n=5) and volleyball (n=12) teams	Cybex NORM	Knee flexion/extension at 60º/sec	Normalised PT. Independent T-test. Statistical significance set at P<0.05	a) Court sport: ND > D in at 60º/sec (p<0.05) b) Field sport: H:Q ratio D > ND at 60º/sec (p<0.001)
Kong & Burns, 2010	Perception of subject	40 recreationally active subjects (25 males, 15 females)	Biodex System 3 Pro	Knee isometric at 40º - 90º angles. Knee flexion/extension at 60º/sec 180º/sec and 300º/sec	ANOVA Statistical significance was set at p < 0.05. Post-hoc analysis	a) Knee flexors D > ND at 300º/sec (p=0.006). b) H:Q ratio D > ND (p=0.046)
Lanshammer & Ribom, 2011	Hand dominance (Preferred side)	159 Swedish women (randomly selected)	Cybex II	Knee flexion/extension at 90º/sec	Student's T-test when comparing the differences between the two legs	a) Extensors: D 5.3% > ND (p<0.009) b) Flexors: ND 8.6% > D (p<0.001) c) Knee H:Q ratio of the D leg was 46 ± 0.08% as compared with 53 ± 0.09% in the ND leg (p> 0.001).

Study	Limb dominance	Subjects	Isokinetic dynamometer	Test Protocol	Statistics used	Results
Markou & Vagenas, 2006	Three different types of dominance: *Directional (left vs right side) *Absolute (maximum vs minimum) *Fluctuating (D vs ND)	24 Greek elite male national volleyball players	Cybex II+	Knee flexion/extension at 60º/sec Shoulder internal/external rotation at 60º/sec	Descriptive analysis, multi-variant analysis of variance Statistical significance was tested at p=0.05 probability level	a) PT of shoulder internal rotation: D side p=0.004 b) PT ratio of ER/IR p=0.002 c) PT of knee flexion: D side p=0.019 d) e) PT ratio of H:Q ratio p=0.064
Phillips *et al.*, 2000	Limb dominance was determined by questionnaire (17/200 indicated left as D for lower limbs)	200 subjects (20 male and 20 female subjects from each decade of age from 20 to 69 years)	Kin-Com	Knee extension/flexion Isometric testing at 60º/sec Isokinetic testing at 60º/sec and 120º/sec	Intra- and inter-session reliability Regression analysis. ANOVA	a) Males: D limb 4.4% > ND limb at 120º/sec for PT. b) Females: D limb 5.6 – 7.7%> ND limb in all three tests for knee extensors for PT.
Radjo *et al.*, 2013	Did not specify	68 cadet basketball players (age 16.61 ± 0.49) Gender was not specified.	Biodex	Knee flexion/extension at 60º/sec	Central dispersion parameters. Independent T-test. Factor analysis	a) Knee extensors PT R limb > L limb (p=0.019) b) Knee flexors PT R limb > L limb (p=0.000) d) Bilateral difference for H:Q ratio was not significant (p=0.027)

*PT = Peak torque (Nm), sec = secondes, ER/IR = External rotation/Internal rotation, H:Q = Hamstring/Quadriceps ratio, D = Dominant, ND = Non-dominant, R = Right, L = Left, p = practical significance

2.4 CONCLUSION

Netball is a physically demanding unilateral sport that requires players to perform various movements, for example throwing action, running, repetitive jumping and landing movements, repeated short runs, quick stops and starts, as well as sudden agility movements. These are weight-bearing movements, mainly supported by one limb. Unilateral movements have an effect on the body's morphological and strength profiles. During a jumping-landing movement the weight of the body is placed on the D leg, while the ND leg is protected from direct impact. These unilateral movements may lead to bilateral differences between D and ND limbs. Factors that contribute to bilateral differences between limbs include dominance, coordination, current muscle imbalances, injury history and the specific movement demands of the sport code. The percentage of bilateral difference between the D and ND side of the upper and lower limb can be determined by means of unilateral tests. Research has found that there is an adaptation of anthropometrical and strength measurements in sporting codes that predominantly use movements from a unilateral base and it has been found that limb dominance does have an effect on the bilateral differences.

Anthropometric studies previously done on netball players focused on the percentage of body fat and the somatotype, but only limited research could be found on bilateral differences that led to asymmetry in the anthropometric measurement of netball players. Sporting codes other than netball that predominantly use unilateral movements differ significantly between the D and ND limbs concerning different anthropometrical measurements. Research has found statistical significant bilateral differences for some anthropometrical variables of various sporting codes predominantly using unilateral movements. However, some contradictory studies showed no significant differences between the D and ND sides for any anthropometrical variables of different sporting codes.

Bilateral strength differences are presented in sports that involve more unilateral movements. Bilateral strength differences higher than 10-15% among the D and ND limb in muscles of the lower body may have an undesirable effect on performance and needs attention. Studies have shown a significant bilateral difference between the D and ND isokinetic knee strength. Bilateral differences exist not only in muscle strength values, but also between the percentage ratios of the agonist and antagonist muscle groups at a joint of the D and ND limbs. Agonist and antagonist muscle ratios of athletes participating in different sporting codes at similar competing levels may depend on the specific demands of the sport. Throughout the literature, it can be noted that there is different isokinetic strength asymmetries for active and inactive subjects, as well as for athletes in different sporting codes. There are contradictions in the literature and limited research has been done on the netball sporting code of university-level players.

The bilateral difference is an occurrence that deserves attention because it demonstrates that the type of movement used (bilaterally or unilaterally) can have an effect on isokinetic muscle strength. Limited research was done on the general association between bilateral differences, limb dominance and the effect on performance. Dynamic movements are regularly used in sport practice. The conditions in which exercises are performed must be taken into consideration when planning a training programme, not only as a form of variation but also as a way to increase training adaptation, especially for athletes who focus on unilateral movements. To achieve a more specific training approach, better understanding of the occurrence of bilateral differences and their interaction with sport performance is required.

REFERENCES

Augustsson, J. & Thomee, R. 2000. Ability of closed and open kinetic chain tests of muscular strength to assess functional performance. *Scandinavian journal of medicine & science in sports*. 10(3):164-168.

Bale, P. & Hunt, S. 1986. The physique, body composition and training variables of elite and good netball players in relation to playing position. *Australian journal of science and medicine in sport.* 18(4):16-19.

Bamaç, B., Çolak, T., Özbek, A., Çolak, S., Cinel, Y. & Yenigün, Ö. 2008. Isokinetic performance in elite volleyball and basketball players. 40(2):182-188.

Berg, K., Blanke, D. & Miller, M. 1985. Muscular fitness profile of female college basketball players. *The journal of orthopaedic and sports physical therapy.* 7(2):59–64.

Blackburn, A. & Knüsel, C.J. 2006. Hand dominance and bilateral asymmetry of the epicondylar breadth of the humerus. *Current anthropology.* 47(2):377-382.

Bloomfield, J., Polman, R., O'Donoghue, P. & McNaughton L. 2007. Effective speed and agility conditioning methodology for random intermittent dynamic type sports. *Journal of strength and conditioning research.* 21(4):1093-1100.

Botton, C.E., Radaelli, R., Wilhem, E.N., Silva, B.G.C., Brown, L.E. & Pinto, R.S. 2013. Bilateral deficit between concentric and isometric muscle actions. *Isokinetics and exercise science.* 21(2):161-165.

Brown, A.M., Zifchock, R.A, & Hillstrom, H.J. 2014. The effects of limb dominance and fatigue on running biomechanics. *Gait & posture*. 39(3): 915-919.

Callaghan, M.J., McCarthy, C.J., Al-Omar, A. & Oldham, J.A. 2000. The reproducibility of multi joint isokinetic and isometric assessments in a healthy and patient population. *Clinical biomechanics*. 15(9):678-683.

Carpes, F.P., Mota, C.B. & Faria, I.E. 2010. On the bilateral asymmetry during running and cycling – A review considering leg preference. *Physical therapy in sport.* 11(4):136-142.

Carter J.E.L. & Heath H.B. 1990. Somatotyping development and application. Cambridge: Cambridge University Press.

Carter, J.E. & Stewart, A.D. 2012. Physique: Phenotype, somatotype and 3D scanning. (*In* Stewart, A, & Sutton, L. Body composition in sport, exercise and health. Abingdon, Oxon: New York p. 64-86).

Carvalho, H.M., Coelho-e-Silva, M., Valente-dos-Santos, J., Gonçalves, R.S., Phllipaerts, R. & Malina, R. 2012. Scaling lower-limb isokinetic strength for biological maturation and body size in adolescent basketball players. *European journal of applied physiology.* 112(8):2881-2889.

Chad, K.E. & Steele. 1991. Physiological characteristics of skilled netball players. *National Sport Research Centre. in Australian Sport Commission. 1-13.*

Chang, R.Y., Briffa, K.N. & Edmondston, S. J. 2013. Bone mineral density and body composition in elite female golf and netball players. *European journal of sport science.* 13(2): 183-190

Cheung, R.T.H., Smith, A.W. & Wong, D.P. 2012. H:Q ratios and bilateral leg strength in college field and court sports players. *Journal of human kinetics.* 33:63-71.

Čižmek, A., Ohnjec, K., Vučetić, V. & Gruić, I. 2010. Morphological differences of elite Croatian female handball players according to their game position. *Hrvatski sportskomedicinski vjesnik.* 25(2):122-127.

Coombs, R. & Carbutt, G. 2002. Development in the use of the hamstring/quadriceps ratio for the assessment of muscle balance. *Journal of sport science and medicine*. 1(3):56-62.

Copeland, S. 1993. Throwing injuries of the shoulder. *British journal of sport medicine.* 27(4):221-227.

Cormack, S.J., Smith, R. L., Mooney, M.M., Young, W.B. & O'Brien, B.J. 2014. Accelerometer load as a measure of activity profile in different standards of netball match play. *International journal of sports physiology & performance*. 9(2):283-291.

Cybex Norm™ Testing and rehabilitation system user's guide. 1996. *Cybex international, Inc.* Ronkonkoma, New York – United States of America.

Davidson, P.R. & Wolpert, D.M. 2003. Motor learning and prediction in a variable environment. *Current opinion in neurobiology.* 13(2):232-237.

Dervišević, E. & Hadžić, V. 2012. Quadriceps and hamstrings strength in team sports: Basketball, football and volleyball. *Isokinetics and exercise science.* 20(4):293-300.

Duarte, J.P., Valente-dos-Santos, J., Coelho-e-Silva, M.J., Couto, P., Costa, D., Martinho, D., Seabra, A., Cyrino, E.S., Conde, J., Rosado J. & Gonc R.S. 2018. Reproducibility of isokinetic strength assessment of knee muscle actions in adult athletes: Torques and antagonist-agonist ratios derived at the same angle position. *PLoS ONE*, 13(8). https://doi-org.nwulib.nwu.ac.za/10.1371/journal.pone.0202261.

Ferreira, M.A. & Spamer, EJ. 2010. Biomechanical, anthropometrical and physical profile of elite university netball players and the relationship to muscular skeletal injuries. *South African journal of research in sport, physical education and recreation.* 32(1):57-67.

Fort-Vanmeerhaeghe, A., Gual, G., Romero-Rodriques, D. & Unnithan, V. 2016. Lower limb neuromuscular asymmetry in volleyball and basketball players. *Journal of human kinetics*. 50(1):135-143.

Fort-Vanmeerhaeghe, A., Montalvo, A.M., Sitjà-Rabert, M., Kiefer, A. W. & Myer, G. D. 2015. Neuromuscular asymmetries in the lower limbs of elite female youth basketball players and the application of the skilful limb model of comparison. *Physical therapy in sport*. 16(4):317-323.

Gamble, P. 2011. Physical preparation for netball – Part 1: Needs analysis and injury epidemiology. *UK strength and conditioning association.* 22:10-15.

Hadzic, V., Sattler, T., Veselko, M., Markovic, G. & Dervisevic, E. 2014. Strength asymmetry of the shoulders in elite volleyball players. *Journal of athletic training.* 49(3):338-344.

Hart, N.H., Nimphius, S., Spiteri, T. & Newton, R. U. 2014. Leg strength and lean mass symmetry influences kicking performance in Australian football. *Journal of sports science & medicine.* 13(1):157-165.

Hebbal, G.V. & Mysorekar, W.R. 2006. Evaluation of some tasks used for specifying handedness and footedness. *Perceptual and motor skills.* 102(1):163-164.

Hetherington, S., King. S., Visentin. D. & Bird. M.L. 2009. Kinematic and kinetic study of netball shoulder pass. *International journal of exercise science.* 2(4):243-253.

Hewett, T.E., Myer, G.D. & Zazulak, B.T. 2008. Hamstring to quadriceps peak torque ratios diverge between sexes with increasing isokinetic angular velocity. *Journal of science and medicine in sport.* 11(5):452-459.

Hewit, J.K., Cronin, J.B. & Hume, P.A. 2012a. Asymmetry in multi-directional jumping tasks. *Physical therapy in sport.* 13(4):238-242.

Hewit, J.K., Cronin, J.B. & Hume, P.A. 2012b. Understanding change of direction performance: A technical analysis of a 180° aerial catch and turn task. *International journal of sports science & coaching*. 7(3):503-514.

Hoffman, J. 2006. Fitness and health assessment. In *Norms for fitness, performance and health.* Human Kinetics, United States of America.

Hopper, D. 1997. Somatotype in high performance female netball players may influence player position and the incidence of lower limb and back injuries. *British journal of sport medicine.* 31(3):197-199.

Hopper, D., Lo, S.K., Kirkham, C. & Elliot, B. 1992. Landing patterns in netball: Analysis of an international game. *British journal of sport medicine.* 26(2):101–106.

Humac2014®/Norm™. 2014. Application program. *Computer Sports Medicine, Inc.* Stoughton, MA, United states of America.

International Netball Federation (INF). 2013. History of netball. http://www.netball.org/netball/history-of-netball Date of access: 07 Jun 2016.

Kabacinski, J., Murawa, M., Mackala, K. & Dworak, L.B. 2018. Knee strength ratios in competitive female athletes. *Plos one*. 13(1): e0191077. https://doi.org/10.1371/journal.pone.0191077 .

Knapik, J.J., Bauman C.L., Jones, B.H., Harris, J.M. & Vaughan L. 1991. Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *American journal of sports medicine.* 19(1):76-81.

Kong, P. W. & Burns, S. F. 2010. Bilateral difference in hamstrings to quadriceps ratio in healthy males and females. *Physical therapy in sport*. 11(1):12-17.

Kovačević, E., Abazović, E., Bradić, J. & Vrcić, M. 2012. The predictive value of isokinetic assessment on the explosive strength of the lower extremities. *Homo sporticus*. 14(1):49-55.

Krichan, K. & Kanchan, T. 2016. Forensic and anthropological application of body asymmetry: A comment on Gutnik *et al*. (2015). *Perceptual and motor skills.* 122(2):578-582.

Kruger, A., De Ridder, H., Underhay, C. & Grobbelaar, H. 2005. Die voorkoms van morfologiese asimmetrie by elite internasionale manlike spiesgooiers. *South African journal for research in sport, physical education and recreation.* 27(2):47-55.

Krzykała, M. & Leszczyński, P. 2015. Asymmetry in body composition in female hockey players. *Homo – Journal of comparative human biology*. 66(4):379-386.

Land, H. & Gordon, S. 2011. What is normal isokinetic shoulder strength or strength ratios? A systematic review. *Isokinetics & exercise science*. 19(4):231-241.

Lanshammer, K. & Ribom E.L. 2011. Differences in muscle strength in dominant and non-dominant leg in females aged 20-39 – A population-based study. *Physical therapy in sport,* 12:76-79.

Lavipour, D. 2009. Development of a netball specific dynamic balance assessment. Auckland, New Zealand: Auckland University of Technology. (Thesis). 98 p

Manning, J.T. & Pickup, L.J. 1998. Symmetry and performance in middle distance runners. *International journal of sport medicine.* 19(3):205 – 209.

Markou, S. & Vagenas, G. 2006. Multivariate isokinetic asymmetry of the knee and shoulder in elite volleyball players. *European journal of sport science.* 6(1):71-80.

Maulder, P. S. 2013. Dominant limb asymmetry associated with prospective injury occurrence. *South African journal or research in sport, physical education and recreation*. 35(1):121-131

McCurdy, K. & Conner, C. 2003. Unilateral support resistance training incorporating the hip and knee. *Strength conditioning journal.* 25(2):45–51.

Miller, L.E., Nickols-Richardson, S.M., Wootten, D.F., Ramp, W.K. & Herbert, W.G. 2004. Relationships among bone mineral density, body composition and isokinetic strength in young women. *Clacified tissue international.* 74(3):229-235.

Montgomery, P.G., Pyne, D.B. & Minahan, C.L. 2010. The physical and physiological demands of basketball training and competition. *International journal of sport physiology and performance.* 5(1):75-86.

Olmo, J., López-Illescas, A., Martín, I., Jato, S. & Rodríquez. 2006. Knee flexion and extension strength and H/Q ratio in high-level track and field athletes. *Isokinetic and exercise science.* 14(3):279-289.

Otago, L. 2004. Kinetic analysis of landing in netball: Is a footwork rule change required to decrease ACL injuries? *Journal of science and medicine in sport.* 7(1):85–95.

Oxford English Dictionaries. 2017. Asymmetry. https://en.oxforddictionaries.com/definition/asymmetry Date of access: 19 Oct. 17.

Pappas, E. & Carpes, F.P. 2012. Lower extremity kinematic asymmetry in male and female athletes performing jump-landing tasks. *Journal of science and medicine in sport.* 15(1):87-92.

Perrin D.H. 1986. Reliability of isokinetic measures. *Athletic training,* 21: 319-326.

Phillips, B.A., Lo, S.K. & Mastaglia, F.L. 2000. Isokinetic and isometric torque values using a Kin-Com dynamometer in normal subjects aged 20 – 69 year. *Isokinetics and exercise science*. 8(3):147-159.

Radjo, I., Handzic, O., Manic, G., Mahmutovic, I., Alic, H. & Colakhodzic, E. 2013. Asymmetry in strength of thigh muscles in basketball players. *Technics technologies education management.* 8(2):723-728.

Ribeiro, B.G., Mota, H.R., Sampaio-Jorge, F., Morales, A.P. & Leite, T.C. 2015. Correlation between body composition and the performance of vertical jumps in basketball players. *Journal of exercise physiology online.* 18(5):69-78.

Rosene, J.M., Fogarty, T. D. & Mahaffey, B.L. 2001. Isokinetic hamstrings:quadriceps ratios in intercollegiate athletes. *Journal of athletic training.* 36(4):378-383.

Rynkiewicz, M., Rynkiewicz, T., Zurek, P., Ziemann, E. & Szymanik, R. 2013. Asymmetry of muscle mass distribution in tennis players. *Trends in sport sciences.* 1(20):47-53.

Sadeghi, H., Allard, P., Prince, F. & Labelle, H. 2000. Symmetry and limb dominance in able-bodies gait: A review. *Gait and Posture.* 12(1):34-45.

Sale, D. 1988. Neural adaptation to resistance training. *Medicine and science in sports exercise.* 20(5):135–145.

Sapega, A. & Drillings, G. 1983. The definition and assessment of muscular power. *Journal of orthopaedic & sports physical therapy.* 5(1):7-9.

Serrein, D.J., Ivry, B.I. & Swinnen,S.P. 2006. Dynamics of hemispheric specialization and integration in the context of motor control. *Nature reviews neuroscience*. 7(2):160–167.

Shakespear, W. & Caldow, M. 2009. Netball: steps to success. 2nd Edition. Champaign, IL: Human Kinetics.

Siquera, C.M., Pelegrini, F.R., Fontana, M.F. & Greve J.M. 2002. Isokinetic dynamometry of knee flexors and extensors: Comparative study among non-athletes, jumper athletes and runner athletes. *Revista do hospital das clinicas*. 57 (1):19-24.

Soh, K.G., Husain, R. & Soh, K.L. 2006. Fitness profile among Malaysian netball players. *Journal of physical education & recreation (Hong Kong).* 12(2):40-44.

Soh, K.G., Soh, K.L., Ruby, H., Sofian, O.F.M., Aminuddin, Y. & Marjohan, J. 2009. Comparison of physical profile of Malaysian basketball and netball players by playing position. *African journal for physical, health education, recreation and dance.* 5(2): 278-284.

Terblanche, E. & Venter, R.E. 2009. The effect of backward training on the speed, agility and power of netball players. *South African journal for research in sport, physical education and recreation.* 31(2):135-145.

Tomkinson, G.R., Popovic, N. & Martin, M. 2003. Bilateral symmetry and the competitive standard attained in elite and sub-elite sport. *Journal of sport science.* 21(3): 201-211.

Toonstra, J. & Mattacola, C.G. 2013. Test-retest reliability and validity of isometric knee-flexion and –extension measurement using 3 methods of assessing muscle strength. *Journal of sport rehabilitation.* Tech report 7(1):1-5. https://doi.org/10.1123/jsr.2013.TR7

Trivers, R., Fink, B., Russel, M., McCarty, K., James, B. & Palestis, B. 2014. Lower body symmetry and running performance in elite Jamaican track and field athletes. *Plos one.* 9(11):e113106. doi:10.1371/journal.pone.0113106. Date of access: 04 October 2016.

Van den Tillaar, R. & Ettema, G. 2004. Effect of body size and gender in overarm throwing performance. *European journal of applied physiology.* 91(4):413-418.

Velotta, J., Weyer, J., Ramirez, A., Winstead, J. & Bahamonde, R. 2011. Relationship between leg dominance test and type of task. *Portuguese journal of sport science.* 11(2):1035-1038.

Venter, R.E., Fourie, L., Ferreira, S. & Terblanche, E. 2005. Physical and physiological profiles of Boland netball players. *South African journal of sport medicine.* 17(2):3-7.

Woodlands, J. 2006. The netball handbook. 1st Edition. Champaign, IL: Human Kinetics.

Xaverova, Z., Drinberger, J., Lehnert, M., Belka J., Wagner, H. & Orechovska, K. 2015. Isokinetic strength profile of elite female handball players. *Journal of human kinetics*

CHAPTER 3 - ARTICLE 1

UPPER AND LOWER BODY BILATERAL DIFFERENCES IN ANTHROPOMETRIC MEASUREMENT OF UNIVERSITY LEVEL NETBALL PLAYERS

UPPER AND LOWER BODY BILATERAL DIFFERENCES IN ANTHROPOMETRIC MEASUREMENTS OF UNIVERSITY LEVEL NETBALL PLAYERS

Bo- en onderlyf- bilaterale verskille in antropometriese metings van universiteitsvlaknetbalspelers

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ABSTRACT

The aim of this study was to determine the presence of bilateral differences in upper as well as lower body of anthropometric measurements among netball players. Forty-four female university level players of a university in the North West province, with an average age of 20.2±1.4 years, stature of 175.7±7.2cm and body mass of 72.5±8.8kg, were tested. The results showed that out of all the anthropometric measurements taken (traits that were part of a bilateral pair) only biceps skinfold (17.93±28.85%) had the largest bilateral difference and support the statistical and practical significant difference of p=0.00 (d=0.34). Limited studies in other intermitted sport codes have found bilateral differences in other anthropometrical sites, supporting the incidence of bilateral development. These findings show that netball players tend to marginally develop asymmetrically owing to the demands of the sport and their unilateral movements. Thus, we conclude that university level netball players show some marginally significant difference between the dominant and non-dominant side.

Key words: Anthropometry, bilateral differences; netball; upper and lower body

INTRODUCTION

Symmetry is associated with balance and harmony in the human body any deviation from symmetry is known as asymmetry (Rynkiewicz *et al*., 2013) due to bilateral differences. Unilateral tasks or movements are the reason for the development of bilateral differences between dominant (D) and non-dominant (ND) limbs (Cheung *et al*., 2012). Elevation from, or landing on one leg during a rebound, or throwing an object with one arm, is seen as an unilateral movement (McCurdy & Conner, 2003). In many cases, when comparing unilateral tasks, some level of functional asymmetry will be present (Maulder, 2013). Functional asymmetric results, due to one-sided lifestyles or actions in which one side of the body is continuously used, lead to bilateral differences (Strydom, 2000). According to Pirnay *et al.* (1987) and Merletti *et al.* (1994), the unilateral demands on the D limbs, leads to development and changes in body composition that differ from that of the ND side. Furthermore, what is known as anthropometric asymmetry (bilateral difference) is often found in participants in sport requiring unilateral movements, for example tennis (Pirnay *et al.*, 1987; Green *et al.*, 1996), javelin throwing (Kruger *et al.*, 2005) and fast bowling in cricket (Engstrom *et al.*, 1999; Grobbelaar & De Ridder, 2001).

The importance of studies on bilateral differences in athletes is emphasized by the negative consequences thereof as stated by Starosta (1989), who reported that unilateral training and movements have a negative influence on range of motion and optimal performance. Sward (1992) reported the prevalence of scoliosis in up to 80% of athletes with unilateral load on the trunk and shoulders, such as javelin throwers and tennis players. According to Grobbelaar and De Ridder (2001), fast bowlers in cricket show similar unilateral loads as athletes in tennis and javelin. From an anthropometrical viewpoint, limited information with regards to the prevalence of bilateral differences in netball players could be found in the literature. Unilateral movements may vary from player to player due to the demands of the position and their nature usually depends on the dominance of the netball player (Hopper *et al*., 1992). Movements more specific to netball, such as running, jumping, multi-directional changes and throwing, are performed predominantly from a unilateral platform. This means it is a weight-bearing movement supported by only one leg or one-handed passes, where the D side is used (McCurdy & Conner, 2003:45; Pappas & Carpes, 2012:90).

The question arises whether bilateral differences from an anthropometrical viewpoint is found in the upper as well as the lower body of university level netball players and if so, what the extent of bilateral differences is. Information pertaining of bilateral differences in the upper and lower body of netball players could be of great value to sport scientists and coaches. Exercise programs could be developed specifically for the needs of these netball players and implemented appropriately, firstly to prevent, and secondly to remedy the occurrence of such bilateral

differences. In the end, this will improve their performance and help with the conditioning of these players. Better understanding of the bilateral differences mechanism and the effect on performance will enable a more targeted approach to specific training (Carpes *et al*., 2010).

PURPOSE OF STUDY

The purposes of this article were therefore to determine, if university level netball players show significant presence of bilateral differences in the upper and lower body, and if so, which of the anthropometric variables (skinfolds, girths, breadths and lengths) show the greatest degree of bilateral differences.

METHODOLOGY

Research design

This study followed an experimental test design with convenience sampling.

Participants and ethical clearance

Forty-four female university level netball players at a university of the North West province, with an average age of 20.2±1.4 years, were tested. They had an average stature of 175.7±7.2cm and an average body mass of 72.5±8.8kg. This study made use of an experimental test design with convenience sampling. Only players who provided voluntary consent, and complied with the inclusion and exclusion criteria, were allowed to participate in this study. Prior to data collection, a project letter was sent to the university's department of sport, coaches and managers, explaining the purpose of the study and seeking permission.

Approval was given by all relevant role players. The players were tested in 2016, during the in-season phase of their periodization cycle. Risks for these participants were minimal and all monitoring and safety measurements were in place. Ethical approval for this study was obtained from the Human Research Ethics Committee of the Faculty of Health Science at the North-West University (NWU-00359-15-A1).

Procedures

A week prior to testing, an information session was held to explain the purpose and risks of the study, as well as the procedures involved in the testing protocol. This information was also specified in the consent form. The informed consent forms were handed out during the session and were only required back on the day of testing. Participation was entirely voluntary, which was clearly printed on the informed consent form.

The participants' demographic information was collected by means of a general information questionnaire. Limb dominance was determined by self-declaration (Coren & Porac, 1978; Maulder & Cronin, 2005).

Measurements

Anthropometry measurements

Anthropometric measurements were taken early in the morning, before breakfast or training, according to the International Society for the Advancement of Kinanthropometry (ISAK) protocol (Stewart *et al*., 2011) by a level II ISAK-accredited anthropometrist. Stature, body mass, eight skinfolds, six girths, five segment lengths and four bone breadths were measured on the D and ND side of each of the participants. The technical error of measurement (TEM) was calculated making use of the formula of Pederson and Gore (1996:85) (Perini *et al.,* 2005:87). The relative TEM scores for the skinfolds showed less than 3.24% and 5.75% for the D and ND side respectively. For the girth measurements the TEM revealed less than 1.14% and 0.92% for the D and ND side respectively. The TEM scores for the length measurements less than 0.98% and 0.90% for the D and ND side respectively. For the breadths measurements the TEM scores revealed less than 1.69% and 1.53% for the D and ND side respectively. Perini *et al.* (2005:88) stated that for the intra-evaluator that a difference of 5 – 7.5% relative TEM values is considered as acceptable for skinfolds and 1 – 1.5% for the other anthropometrical measurements.

Statistical analysis

The Statistical Data Processing package (IBM SPSS Statistics Version 25) was used to compile descriptive statistics (averages, standard deviations, 90% confidence intervals (CI), minimum and maximum values). Due to the small sample size, statistical significant difference of all measurements taken for the D and ND side, a dependent t-test ($p \leq 0.05$) was performed for the total group (D and ND of the upper and lower limbs) regarding the bilateral differences. Effect size (ES) was also calculated for the total group (D and ND of the upper and lower limbs) ($d = \frac{M1-M2}{s}$), and Cohen's effect size for practical significance was used, as reported by Ellis and Steyn (2003). Guidelines for effect size were: Small effect – d=0.2; medium effect – d=0.5 and large effect – d=0.8. The 90% CI was qualitatively interpreted using the following thresholds: <0.19, trivial; 0.2 to 0.59, small; 0.6 to 0.1.19, medium; 1.2 to 1.99, large; 2.0 to 4.0, very large and; > 4, vast differences (Hopkins, 2009) to determine the likelihood that the true value of the effect represents substantially beneficial or detrimental change. The smallest practically meaningful effect was considered 0.2 either positive or negative – with values implicating either the D (positive) or the ND (negative). Effects when the CI overlapped, small positive or small negative effects were

defined as unclear. Effect sizes could be beneficial/detrimental were either positively or negatively medium to vast differences with either the upper or lower limit of the 90% CI not exceeding a trivial ES (<0.19) on either side.

RESULTS

Descriptive statistics for the variables used in this study are presented in Table 1. When comparing the mean scores from Table 1, the extent of bilateral differences between the D and ND sides is evenly disturbed for all skinfold variables. It can be noted that the data for the measurements is widely spread between the min and max value for skinfolds and girth measurements. This is due to the large group of female netball players with a different body sizes (skinfold thickness and muscle volume) and different playing positions. This wide spread data is also due to the different fitness and competition levels of the players that trained and participated in different divisions at university level.

Four of the eight skinfolds achieved larger measurements on the ND side. All mean girth variables showed higher values on the D side, whereas the ND side scored higher in all mean length variables. For the breadth measurements, half of the D side's variables were larger than the ND side's variables. The mean scores for the sum of six skinfolds, body fat percentage, muscle mass, and skeletal mass showed higher values on the D side. Bone density showed no difference between the D and ND sides.

Table 2 represents the statistical and practical significant differences between the D and ND sides. The measurements of the biceps (p=0.00, d=0.35), triceps (p=0.02, d=0.18) and abdominal (p=0.00, d=0.24) skinfolds showed statistical as well as practical significant differences between the D and ND sides, with the triceps and abdominal skinfolds being smaller on the ND side, and a smaller biceps skinfold on the D side. The subscapular skinfold showed no statistical significance (p=0.10, d=0.15) although a small practical significance difference between the D and ND side was determined, where the D side showed smaller values. The iliac crest, supraspinal, thigh and calf skinfolds did not show any statistical or practical significant difference between the D and ND sides.

As seen in the descriptive statistics, all girth measurements from the D side were greater than those on the ND side. Only two of these measurements, flexed upper arm (p=0.00, d=0.16) and forearm girth (p=0.00, d=0.36), showed statistical and small practical significant differences. The relaxed upper arm (p=0.04, d=0.07) and mid-thigh girths (p=0.02, d=0.11) showed statistical significant differences between the D and ND side. Of all measured girths, the D side measurements exceeded those of the ND side.

Although all the length measurements of the ND side surpass those on the D side, only the radial-stylion (forearm) length (p=0.00, d=0.32) showed statistical significant differences and a small practical significant difference between the D and ND sides. For the breadth measurements, only the wrist and femur breadths showed statistical significant differences, with the D side (p=0.05, d=0.10 and p=0.03, d=0.12 respectively) having larger values. The humerus and ankle breadth showed no statistical or practical significant differences between the D and ND sides

Regarding the compiled body composition between the D and ND sides, the sum of six skinfolds (p=0.00), bone density (p=0.00), body fat percentage (p=0.00), and muscle mass (kg) (p=0.00) attained statistical significant differences, where the D side had the larger values. Only muscle mass showed a small practical significant difference (d=0.18) between the D and ND sides. Skeletal mass showed no statistical or practical significant difference between the D and ND sides.

Table 1: Descriptive statistics for dominant and non-dominant anthropometrical variables of university level netball players

N44	**Dominant**				**D - TEM**	**Non-Dominant**				**ND – TEM**
	Min	**Max**	**Mean**	**Std. Dev**		**Min**	**Max**	**Mean**	**Std. Dev**	
Age (yrs)	18.00	25.00	20.02	1.39						
Stature (cm)	148.00	191.00	175.68	7.17						
Mass (kg)	58.90	92.95	72.50	8.82						
Skinfolds: (mm)										
Biceps	3.20	21.70	8.78	4.11	3.24	4.20	31.00	10.66	5.58	5.75
Triceps	8.00	35.10	17.83	5.52	2.58	8.90	28.40	16.82	4.71	4.98
Subscapular	6.40	27.07	11.56	4.39	2.30	6.93	34.67	12.21	5.57	2.59
Illiac crest	8.60	35.53	18.26	6.45	1.80	9.00	37.00	18.21	6.49	2.92
Supraspinal	5.80	30.50	13.19	5.51	2.06	4.70	29.80	12.68	5.90	5.75
Abdominal	7.80	31.80	18.37	5.15	1.59	9.30	25.65	17.12	4.60	2.11
Thigh	12.00	41.00	25.93	7.62	1.60	12.40	43.80	26.07	7.98	1.46
Calf	6.20	33.20	16.93	4.99	1.40	6.13	32.20	17.01	5.19	2.05
Girth (cm)										
Relaxed upper arm	24.55	35.10	28.31	2.56	0.85	24.40	35.25	28.12	2.54	0.92
Flexed upper arm	26.10	36.05	29.46	2.18	0.82	25.15	36.30	29.13	2.29	0.82

N44	Dominant				D - TEM	Non-Dominant				ND – TEM
Forearm	21.80	28.75	25.08	1.34	0.64	21.20	27.35	24.61	1.23	0.64
Wrist	14.30	17.75	15.80	0.74	1.14	14.55	17.55	15.78	0.73	0.73
Thigh	48.80	64.17	56.26	3.51	0.38	49.15	63.87	55.88	3.69	0.43
Calf	33.10	44.80	38.39	2.54	0.30	33.10	44.40	38.28	2.55	0.46
Length (cm)										
Upper arm	30.00	38.65	34.05	1.62	0.64	29.75	45.50	34.07	2.25	0.60
Forearm	24.45	30.30	26.05	1.19	0.97	24.97	29.90	26.43	1.15	0.90
Hand	18.00	23.00	20.13	0.78	0.98	18.40	22.15	20.20	0.72	0.88
Upper leg	37.45	52.40	44.42	2.92	0.64	37.80	52.50	44.44	2.78	0.37
Lower leg	38.17	52.45	47.29	3.05	0.36	40.25	53.10	47.50	3.30	0.43
Breadths (cm)										
Humerus	5.70	7.05	6.46	0.33	1.18	5.55	7.10	6.49	0.43	0.97
Wrist	4.55	6.35	5.36	0.39	1.69	4.40	6.10	5.32	0.36	1.20
Femur	8.45	10.75	9.60	0.55	1.30	8.50	11.00	9.54	0.55	1.22
Ankle	6.05	7.70	6.84	0.43	0.96	5.90	7.65	6.85	0.47	1.53
Body Composition:										
Sum of 6 skinfolds (mm)	56.70	195.10	104.31	29.68		56.33	177.32	101.91	28.56	
Body density (kg/m^3)	1.02	1.07	1.05	0.01		1.02	1.07	1.05	0.01	
Fat (%)	14.66	36.78	22.07	4.76		13.89	33.81	21.69	4.57	
Muscle mass (kg)	27.50	46.79	37.37	4.15		26.28	46.56	36.61	4.30	
Skeletal mass (kg)	6.41	10.47	8.45	1.03		6.21	10.38	8.42	1.07	

Table 2: Statistical and practical significant differences between dominant and non-dominant anthropometrical variables of university level netball players.

N44	Statistical significant difference (p)	Practical significant difference (d)	Mean Difference between D and ND	90% Confidence Interval of the Difference between D and ND	
				Lower	Upper
Skinfolds: (mm)					
Biceps	0.00#	0.34*	-1.88	-2.71	-1.05
Triceps	0.02#	0.18*	1.01	0.31	1.70
Subscapular	0.10	0.12*	-0.65	-1.29	-0.01
Illiac crest	0.88	0.01	0.05	-0.51	0.61
Supraspinal	0.13	0.09	0.51	-0.04	1.06
Abdominal	0.00#	0.24*	1.25	0.82	1.67
Thigh	0.61	0.02	-0.14	-0.62	0.33
Calf	0.81	0.01	-0.08	-0.61	0.46
Girth (cm)					
Relaxed upper arm	0.04#	0.07	0.19	0.04	0.34
Flexed upper arm	0.00#	0.15*	0.34	0.17	0.51
Forearm	0.00#	0.36*	0.48	0.38	0.58
Wrist	0.64	0.03	0.02	-0.06	0.10
Thigh	0.02#	0.10	0.38	0.11	0.66
Calf	0.18	0.04	0.11	-0.02	0.24
Length (cm)					
Upper arm	0.93	0.01	-0.02	-0.46	0.41
Forearm	0.00#	0.32*	-0.38	-0.59	-0.18
Hand	0.39	0.09	-0.07	-0.21	0.07
Upper leg	0.93	0.01	-0.02	-0.48	0.43
Lower leg	0.15	0.06	-0.21	-0.46	0.03
Breadths (cm)					
Humerus	0.46	0.05	-0.02	-0.07	0.03
Wrist	0.05#	0.10	0.04	0.01	0.07
Femur	0.03#	0.12	0.07	0.02	0.12
Ankle	0.80	0.02	-0.01	-0.05	0.04
Body Composition:					
Sum of 6 skinfolds (mm)	0.00#	0.08	2.40	1.18	3.63
Body density (kg/m^3)	0.00#	0.08	0.00	0.00	0.00
Fat (%)	0.00#	0.08	0.38	0.19	0.58
Muscle mass (kg)	0.00#	0.18*	0.76	0.49	1.03
Sk49:77eletal mass (kg)	0.31	0.03	0.03	-0.02	0.08

** Small Practical Significance (d<0.3)*
*** Medium Practical Significance (d < 0.5)*
 # Statistical Significance level (p≤0.05)

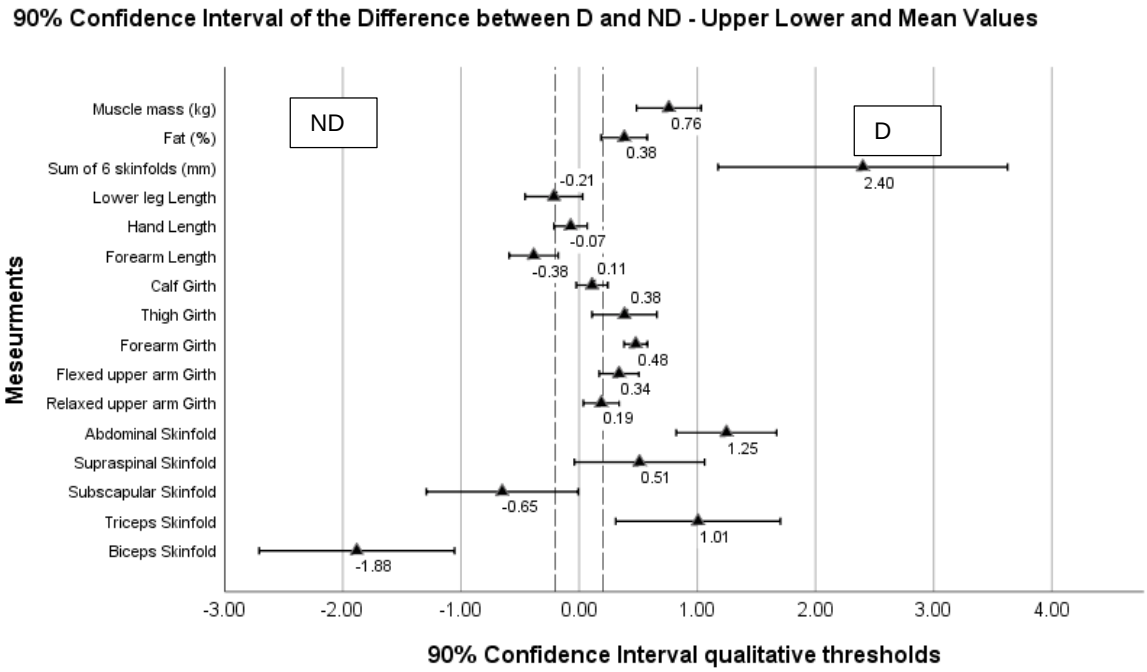

Figure 1: **HI- LOW BAR PLOT OF 90% CI OF THE MEAN DIFFERENCE BETWEEN THE D AND ND SIDES OF THE BODY WITH REGARDS TO THE MEASUREMENTS TAKEN WITH A REFERENCE OF -0.2 TO 0.2 TO INDICATE TRIVIAL TO UNCLEAR EFFECT SIZE OF MEASUREMENTS.**

The high-low bar plot results of Figure 1 depict the mean differences (MD) between D and ND sides and the 90% CI for effect size upper and lower limits of each of the variables that did not indicate trivial to unclear effect size in measurements. From the obtained results of all measured variables: bicep skinfold (MD -1.88: -2.71 and -1.05), subscapular skinfolds (MD -0.65; -1.29 and -0.01), forearm length (MD -0.38;-0.59 and 0.18), and lower leg length (MD -0.21; -0.46 and 0.03) attained small to very large worthwhile effect in favour of the ND side. In this regard the ND side measurements exceeded that of the D side. Furthermore triceps skinfolds (MD 1.01; 0.31 and 1.70), supraspinal skinfold (MD 0.51;-0.04 and 1.06), abdominal skinfold (MD 1.25; 0.82 and 1.67), body fat percentage (MD 0.38; 0.19 and 0.58), and muscle mass (MD 0.76; 0.49 and 1.03) attained small to medium worthwhile effect in favour of the D side. All the girth measurements except the calf girth (MD 0.11; -0.02 and 0.24) [relaxed upper arm (MD 0.19; 0.04 and 0.34), flexed upper arm (MD 0.34; 0.17 and 0.51), forearm girth (MD 0.48; 0.38 and 0.58) and thigh girth (MD 0.38; 0.11 and 0.66)] resulted in a small to medium worthwhile effect in favour of the D side. Only sum of 6 skinfolds (MD 2.40; 1.18 and 3.63) showed medium to very large worthwhile effect in favour of the D side. All other obtained results are considered unclear due to CI upper and lower limit exceeding the smallest positive and smallest negative effect of 0.2.

DISCUSSION

It is evident that the biceps skinfolds and ankle breadths had the highest extent of bilateral differences and both showed statistical and practical significant differences between the D and ND sides of the body. A smaller biceps skinfold on the D side may have a positive effect on performance (Legaz & Eston, 2005), since players with a higher muscle mass and lower body fat mass perform better than players with a lower muscle mass and a higher body fat mass (Ryan-Stewart *et al*., 2018). The biceps skinfold bilateral differences may be present owing to the use of the D arm during the one-handed overhead and shoulder pass that is frequently used (Gamble, 2011; Woodlands 2006;).

When making comparisons with previous research (Blackburn & Knüsel, 2006; Kruger *et al.*, 2005; Krzykała & Leszczyński, 2015). Limited studies have found bilateral differences in other anthropometrical sites supporting the incidence of bilateral difference development in other sporting codes such as basketball, volleyball, hockey, tennis and javelin. The significant differences that were found in this study can be attributed to the unilateral movements in netball.

This study showed statistical significant differences between the D and ND side for the sum of six skinfolds, bone density, body fat percentage, and muscle mass. The sum of six skinfolds and body fat percentage was in favor of the ND side, the measurements were smaller on the ND side than the D side. Only muscle mass showed a small practical significant difference between the D and ND sides. Muscle mass was in favor of the D side, where the muscle mass results where larger than on the ND side. These findings correspond to those of the study of Krzykała and Leszczyński (2015), which found statistical significant differences between the left and right side of the body for muscle mass and fat mass of female hockey players. The bilateral differences in muscle mass can be caused by the side preferences in unilateral movement and the demands of a netball match.

These findings support the notion that netball players tend to develop marginally bilateral differences with the ND side with the larger measurements owing to the unilateral movements of the players.

PRACTICAL APPLICATION

The bilateral difference status of female netball players needs to be monitored. By monitoring the bilateral differences between the D and ND sides, changes can be made to the strength and conditioning programs to minimalize large bilateral differences between the D and ND, which would potentially enhance performance. The monitoring of bilateral development could aid to the

occurrence and then prevention on injuries due to bilateral differences. This should be a high priority in the development of female university level netball players in South Africa.

CONCLUSION

The aim of this study was to determine the presence bilateral differences of upper and lower body anthropometrical measurements among university level netball players. In conclusion, one measurement of the upper body, namely the biceps skinfold, showed practical and statistical significant differences. These findings may be the result of the unilateral demands in movements of netball training and match demands.

Thus we conclude that university level netball players show a marginally significant difference between the D and ND sides in the upper and lower body.

LIMITATIONS AND RECOMMENDATIONS

No control group was used in the study; it is therefore not possible to confirm that the anthropometric bilateral differences is due to only the actions in netball. Studies found that bilateral differences in anthropometrical measurements to be more pronounced in sedentary people than in athletes; athletes tend to be more symmetrical owing to training programmes that involve bilateral exercises. These bilateral differences can be attributed to normal daily activities, where the D limb is more likely to be used than the ND limb. It is recommend that a full detailed injury surveillance and match analysis be included in the research study design so that possible reasons for bilateral differences can be identified. Future studies must take these recommendations into account when developing studies.

REFERENCES

BLACKBURN, A. & KNÜSEL, C.J. (2006). Hand dominance and bilateral asymmetry of the epicondylar breadth of the humerus. *Current Anthropology,* 47(2):377-382.

CARPES, F.P.; MOTA, C.B. & FARIA, I.E. (2010). On the bilateral asymmetry during running and cycling - A review considering leg preference. *Physical Therapy in Sport*, 11(4): 136–142.

CHEUNG, R.T.H.; SMITH, A.W. & WONG, D.P. (2012). H:Q ratios and bilateral leg strength in college field and court sports players. *Journal of Human Kinetics*, 33(1): 63–71.

COREN, S. & PORAC, C. (1978). The validity and reliability of self-report items for the measurement of lateral preference. *British Journal of Psychology,* 69(2): 207-211.

ENGSTROM, C.; WALKER, D.; KIPPERS, V.; HUNTER, J.; HANNA, A. & BUCKLEY, R. (1999). A prospective study on back injury and muscle morphometry in junior cricket fast bowlers. (In Abstracts of the Fifth IOC World Congress on Sport Sciences, Sydney: Sports Medicine Australia, p. 50.)

ELLIS, S.M. & STEYN, H.S. (2003). Practical significance (effect sizes) versus or in combination with statistical significance (p-values). *Management Dynamics,* 12(4): 51-53

FORT-VANMEERHAEGHE, A.; MONTALVO, A. M.; SITJA-RABERT, M.; KIEFER, A. W., & MYER, G. D. (2015). Original research: Neuromuscular asymmetries in the lower limbs of elite female youth basketball players and the application of the skilful limb model of comparison. *Physical Therapy in Sport*, 16(4): 317-323.

GAMBLE, P. (2011). Physical preparation for netball – Part 1: Needs analysis and injury epidemiology. *UK Strength and Conditioning Association,* 22: 10-15.

GREEN, D.J.; FOWLER, D.T.; O'DRISCOLL, J.G.; BLANKSBY, B.A. & TAYLOR, R.R. (1996). Endothelium derived nitric oxide activity in forearm vessels of tennis players. *Journal of Applied Physiology*, 81(2): 943-948

GROBBELAAR, H.W & DE RIDDER, J.H. (2001). Asymmetry in the upper body of high school fast bowlers in cricket in South Africa. *South African Journal for Physical Health Education, Recreation and Dance*, 7(1): 61-76.

HOPKINS, W.G.; BATTERHAM, A.M.; MARSHALL, S.W. & HANIN, J. (2009) Progressive statistics. *Sportscience,* 13:55-70.

HOPPER, D.; LO, S.K.; KIRKHAM, C., & ELLIOT, B. (1992). Landing patterns in netball: Analysis of an international game. *British Journal of Sports Medicine,* 26(2): 101–106.

IBM Corp. Released, 2015. IBM SPSS Statistics for Windows, Version 23.0. 2015.

KRUGER, A.; DE RIDDER, J.H.; UNDERHAY, C. & GROBBELAAR, H. (2005). Die voorkoms van morfologiese asimmetrie by elite-internasionale manlike spiesgooiers. [The appearance of morphologic asymmetry of elite international male javelin throwers]. *South African Journal for Research in Sport, Physical Education and Recreation*, 27(2): 47-55.

KRZYKAŁA, M. & LESZCZYŃSKI, P. (2015). Asymmetry in body composition in female hockey players. *Homo – Journal of Comparative Human Biology*, 66(4): 379-386.

LEGAZ, A. & ESTON, R. (2005). Changes in performance, skinfold thicknesses and fat patterning after three years of intense athletic conditioning in high level runners. *British Journal of Sport Medicine,* 39(11): 851-856.

MAULDER, P. & CRONIN, J. (2005). Horizontal and vertical jump assessment: Reliability, symmetry, discriminative and predictive ability. *Physical Therapy in Sport,* 6: 74-82.

MAULDER, P.S. (2013). Dominant limb asymmetry associated with prospective injury occurrence. *South African Journal for Research in Sport Physical Education and Recreation*, 35(1): 121–131.

M^C^CURDY, K. & CONNER, C. (2003). “Unilateral support resistance training incorporating the hip and knee”. *Strength and Conditioning Journal*, 25(2), p. 45. Hyperlink: [http://www.scopus.com/inward/record.url?eid=2-s2.0-0037963967&partnerID=tZOtx3y1]. Retrieved on 12 June 2018.

MERLETTI, R.; DE LUCA, C.J. & SATHYAN, D. (1994). Electrically evoked myoelectric signals in back muscles: Effect of side dominance. *Journal of Applied Physiology*, 77(5): 2104-2114.

PEDERSON, D. & GORE, C. (1996). Anthropometry measurement error. (*In* Norton, K.L. & Olds, T.S., *eds*. Anthropometrica: a textbook of body measurement for sports and health courses. Marrickville, NSW: Southwood Press. p. 77-96.)

PERINI, T.A.; DE OLIVEIRA, G.L., ORNELLAS, J.S. & DE OLIVEIRA, F.P. (2005). Technical error of measurement in anthropometry. *Revista Brasileira de Medicina do Esporte*, 11(1): 86-90.

PIRNAY, F.; BODEUX, M.; CRIELAARD, J.M. & FRANCHIMONT, P. (1987). Bone mineral content and physical activity. *International Journal of Sports Medicine*, 8(5): 331-335.

RYAN-STEWART, H.; FAULKNER, J. & JOBSON, S. (2018). "The influence of somatotype on anaerobic performance." *Plos One.* 13(5):e0197761. Hyperlink: [https://doi.org/10.1371/journal.pone.0197761]. Retrieved on 12 June 2018.

RYNKIEWICZ, M.; RYNKIEWICZ, T.; ZUREK, P.; ZIEMANN, E. & SZYMANIK, R. (2013). Asymmetry of muscle mass distribution in tennis players. *Trends in Sport Sciences.* 1(20): 47-53.

STASOFT INC, (2013). StatSoft. *Statistica data analysis software system, version 8*. Available at: http://www.statsoft.com/.

STAROSTA, W. (1989). Symetria czy asymetria w doskonaleniu techniki sportowej. [Symmetry or asymmetry in the improvement of sports technique.] *Kultura Fizyczna*, 43(5- 6): 14-1 6. (Abstract in the Sport Discus database: reference number 261 203.)

STEWART, A.; MARFELL-JONES, M.; OLDS, T. & DE RIDDER, H. (2011). International standards for anthropometric assessment. *International Society for the Advancement of Kinanthropometry.* ISAK New Zealand.

STRYDOM, G.L. (2000). Biokinetika handleiding (MBW323). [Biokinetics textbook (MBW323).] Potchefstroom: PU for CHE. (Unpublished.)

SWARD, L. (1992). The thoracolumbar spine in young elite athletes: Current concepts on the effects of physical training. *Sports Medicine*, 13(5): 357-364.

TRIVERS, R.; FINK, B.; RUSSELL, M.; M^{C}CARTY, K.; JAMES, B. & PALESTIS, BG. (2014) Lower body symmetry and running performance in elite Jamaican track and field athletes. *Plos One*. 9(11): e113106. Hyperlink: [https://doi.org/10.1371/journal.pone.0113106]. Retrieved on 12 June 2018.

WOODLANDS, J. (2006). *The netball handbook*. (1st ed.). Champaign, IL: Human Kinetics.

CHAPTER 4 - ARTICLE 2

BILATERAL DIFFERENCES IN UPPER AND LOWER BODY ISOKINETIC STRENGTH OF UNIVERSITY LEVEL NETBALL PLAYERS

BILATERAL DIFFERENCES IN UPPER AND LOWER BODY ISOKINETIC STRENGTH OF UNIVERSITY LEVEL NETBALL PLAYERS

Bilaterale verskille in isokinetiese krag van die bo- en onderlyf vir universiteitsvlak -netbalspelers

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ABSTRACT

The aim of this article was to determine the presence of upper as well as lower body bilateral isokinetic strength differences among university level netball players. Forty-four female university level players of a university in the North West province, with an average age of 20.2±1.4 years, stature of 175.7±7.2cm and body mass of 72.5±8.8kg, were tested. Isokinetic knee extension/flexion and shoulder extension/flexion tests were used to determine the bilateral differences between the dominant (D) and non-dominant (ND) limbs of the lower and upper body. The results showed that there were no statistical or practical significant differences between the D and ND isokinetic knee strength values ($p>0.48$; $d<0.1$). In contrast to these findings, in the upper body, shoulder measurements showed statistical ($p<0.02$) and practical ($d>0.28$) significant differences between the D and ND sides. The shoulder extensor variable showed a greater statistical and practical significant difference ($p=0.00$; $d=0.44$) between the D and ND sides than the shoulder flexors ($p=0.01$; $d=0.29$), even though the shoulder flexion/extension ratio showed no statistical or practical significant difference ($p=0.55$; $d=0.10$). A limited number of studies have found bilateral differences in isokinetic strength between the D and ND limbs, especially in netball, supporting the incidence of bilateral development in other sporting codes. These findings shows that these netball players develop bilateral differences between D and ND limbs in the upper body owing to the demands of the sport and the unilateral movements, concluding that university level netball players show a significant bilateral differences in isokinetic strength between the D and ND sides for the shoulder flexion-extension.

Key words: Bilateral differences; isokinetic strength; knee; netball; shoulder.

INTRODUCTION

Unilateral movements such as running, changing direction, repetitive jumps, landing and passing are required of a netball player (Terblance & Venter, 2009; Chang *et al*., 2013). During these unilateral movements, power is generated by an individual limb, whereas both limbs are used during a bilateral movement (Jakobi & Chilibeck, 2001). An individual who is constantly exposed to unilateral movements can develop bilateral differences between the dominant (D) and non-dominant (ND) limbs (Maulder, 2013). Due to repeated use of the D limb during unilateral movements, it is important to investigate the change in bilateral differences between D and ND limbs (Botton *et al.*, 2013). Repeated use of unilateral movements may lead to bilateral differences in strength of the upper and lower body, between D and ND limbs (Hewit *et al*., 2012; Maulder, 2013).

In order to assess the strength of a moving muscle, different isokinetic dynamometers can be used (Land & Gordon, 2011; Kovačević *et al.*, 2012). This is a reliable and objective method to measure muscle strength and bilateral strength differences in limbs (Bandy & McLaughlin, 1993; Land & Gordon, 2011; Dervišević & Hadžić, 2012). Maximum isokinetic strength is determined by making use of a constant speed with various velocities (1°/sec - 500°/sec) during a concentric and/or eccentric muscle contraction (Cybex Norm, 1996; McDonald *et al*., 2018). It is recommended that bilateral strength differences should be less than 10-15% between the D and ND limb. A larger difference between D and ND limbs may influence performance negatively (Knapik *et al.*, 1991; Hewit *et al.*, 2012; Xaverova *et al*., 2015; Fort-Vanmeerhaeghe *et al.*, 2016).

Limited studies have been done on the isokinetic strength profiles of university-level netball players, therefore other similar court-based sports, such as basketball, were included in the literature review. In one of a few studies done on netball players, Malaysian netball players showed that the overall leg strength for the right and left knee extension at 60°/sec (dominance was not mentioned) was 159.46±26.33Nm and 149.96±26.83Nm respectively, whereas the right and left knee flexion at 60°/sec was 89.67±17.28Nm and 89.39±13.88Nm respectively (Soh *et al*., 2006:42). It is clear from the results (although it was not investigated) that in the knee extension muscles, the bilateral difference was 5.96% between the right and left knee, but less than 1% for the knee flexors. In view of this data, it is therefore imperative to gain more knowledge of isokinetic bilateral strength differences of university-level netball players. In other sports, Thomas *et al*. (2017), found that male basketball players, showed a statistical significant difference ($p<0.05$) of 7-13% between the D and ND limb, with the D limb performing better for peak strength values during an isokinetic knee flexion and extension tests at a velocity of 60°/sec.

The torque required during the acceleration phase of a netball shoulder pass is primarily provided by the concentric contraction of the shoulder flexors (Hetherington *et al*. 2009). No recent studies were available on an isokinetic shoulder extension/flexion test on netball players. Few studies on other intermittent sport codes investigated shoulder internal/external rotation strength measurements (Berg et al., 1985; Chan *et al.* 1996; Markou & Vagenas, 2006). In the early 1980s, in a study done on university-level female basketball players, Berg *et al*. (1985) found that the mean peak torque (PT) for the shoulder extensor for the right and left shoulder (dominance was not mentioned) at a testing velocity of 60°/sec was 44.5 4.9Nm and 41.4± .5Nm respectively. For the shoulder flexors, the mean PT between the right and left shoulders was 34.5±4.6Nm and 33.4±5.0Nm respectively, resulting in a bilateral difference of 6.9% for the shoulder extensors and 3% for the flexors. In a study done on volleyball players the researchers found that volleyball players tended to develop bilateral strength differences between the D and ND shoulder during the isokinetic shoulder internal-external rotation test at a velocity of 60°/sec. For internal rotation the D limb had a larger value than the ND side (difference of 7.23%, $p<0.004$), and for internal rotation, although not statistical significant, the ND limb surpassed the D limb (difference of 4.78%, $p<0.143$ – statistical significances where tested at the $\alpha=0.05$ probability level) (Markou & Vagenas, 2006).

Regarding bilateral strength ratios between the agonist and antagonist muscle (AG:AN), several studies reported a ratio percentage of 50-80% to be an acceptable value (Hewett *et al*., 2008; Kong & Burns, 2010; Cheung *et al*., 2012). Although no consensus could be found, the general acceptance percentage for AG:AN is 60%, depending on different testing velocities, but there seems to be no difference between gender or choice of sport (Rosene *et al*., 2001; Coombs & Carbutt, 2002). Chan *et al.* (1996) state that the shoulder flexion/extension percentage ratios (FLX:EXT) measure between 75% and 85%, but it is noted in a study of Perrin (1993) that overhead sport tends to achieve a percentage ratio of only 50%. For the shoulder external/internal (ER:IR) rotation, the percentage ratio was reported to be between 60% and 80% (Chan *et al.* 1996). Berg *et al*. (1985) found female basketball players' shoulder FLX:EXT percentage ratio to be 77% and 81% for the right and left shoulder respectively at a testing velocity of 60°/sec, with a bilateral difference of 4.9% between the limbs. Regarding the ER:IR, Markou and Vagenas (2006) found that volleyball players showed a percentage ratio of 62.38% and 72.57% for the D and ND shoulder at a testing velocity of 60°/sec, with a significant difference of 15.5% between the limbs. The researchers stated that these bilateral differences in the shoulder were due to the D shoulder developing a systematic superiority in overall muscle strength over years of training (Markou & Vagenas, 2006). In a study done on test subjects participating in sport only on recreational level, Lanshammer and Ribom (2011) found that the hamstring/quadriceps ratio percentage (H:Q) in the D leg was 46±0.08% and in the ND leg 53±0.09% ($p>0.001$) at a testing

velocity of 90º/sec. The reason for the greater percentage ratio of the ND limb, is a greater quadriceps muscle strength in the D leg and weaker hamstring muscle strength than in the ND leg. In the study of Kong and Burns (2010) on recreationally active male and female participants, they found that the H:Q increased when angular velocity (60°/sec, 180°/sec and 300°/sec) was increased ($p<0.001$) in the D leg, which resulted in a higher percentage ratio with regard to all angular velocities. Kong and Burns (2010) concluded that the H:Q differences, with a higher ratio on the D leg, can be attributed to the stronger hamstring muscle in the D leg, while the quadriceps muscle was mostly similar for both legs, and explained that this difference is due to the different training background of the participants.

Because of limited research on isokinetic strength and bilateral differences in the upper and lower limbs of netball players, the following research question arises: Do bilateral differences exist in isokinetic strength variables between D and ND limbs for the upper and lower body muscles of university level netball players? Answers to the above-mentioned research question could be of importance to coaches and sport scientists. Since no recent studies on netball players' shoulder extension/flexion isokinetic testing were available, a gap was found in knowledge of bilateral differences in the upper limbs. The present study will provide a guideline for these professionals regarding scientifically formulated exercise programmes for preventing bilateral differences in netball players.

PURPOSE OF STUDY

To determine whether bilateral differences exist in isokinetic strength variables between the D and ND limbs for the upper and lower body of university level netball players.

METHODOLOGY

Research design

The study followed an experimental test design with convenience sampling.

Participants and ethical clearance

Forty-four female university level netball players at a university in the North-West province, with an average age of 20.2±1.4 years, were tested. They had an average stature of 175.7±7.2cm and an average body mass of 72.5±8.8 kg (Table 1). Only players who provided voluntary consent were allowed to participate in this study. The players were tested during the in-season phase of their periodisation cycle. Ethical approval for this study was obtained from the Human Research Ethics Committee of the Faculty of Health Science at the North-West University (NWU-00359-15-A1).

Procedure

Prior to testing, an information session was presented to the participants to explain the purpose of the study and the procedures involved in the testing. The participants completed a general information questionnaire and an informed consent form prior to the data collection. On the day of testing, the participants' stature and body mass were taken. Limb dominance was determined by self-declaration (Coren & Porac, 1978). Isokinetic strength testing for the upper and lower limb was done on a schedule that accommodated the participants' daily routine (before participating in any form of exercise that day).

Measurements

Isokinetic strength measurements

An isokinetic dynamometer; CYBEX Humac Norm 2014, (Cybex Norm™, 1996), was used for determining isokinetic strength. The CYBEX was calibrated prior to the testing sessions. The calibration was done as indicated by the calibration protocol (Cybex Norm™, 1996). Testing consisted of a concentric knee extension/flextion protocol at a velocity of 60°/sec (Miller *et al.,* 2004; Dervišević & Hadžić, 2012; Boone & Bourgois, 2013) and a concentric shoulder flexion/extension (supine) test at a velocity of 60°/sec (Berg *et al.,* 1985).

Each player completed a lower and upper body warm-up session before the isokinetic strength testing. The warm-up for the lower body consisted of five minutes' cycling on a stationary ergometer at a low intensity (75 Watts) (Lategan, 2012) and specific dynamic stretches for the lower limbs (Papadopoulos *et al.,* 2005). All participants followed the same order of testing by starting with the lower limbs, with sufficient rest after the first part of the test. The upper body warm-up consisted of two minutes' sub-maximal intensity rowing on an upper body ergometer (Malerba *et al.,* 1993), shoulder rolls, wall push-ups and specific dynamic stretches for the upper limbs (Cools *et al.*, 2004).

Each netball player was positioned according to the instructions of the specific protocol (Cybex Norm™, 1996) being used for the different limbs that were tested. A familiarisation set was done prior to the formal test of the knee and shoulder and consisted of two (2) submaximal concentric contractions, after which the player rested for 60 seconds (Parcell *et al*., 2002), followed by the maximal concentric contraction test, which consisted of five (5) repetitions for the knee extension/flexion test (Miller *et al.,* 2004; Dervišević & Hadžić, 2012; Boone & Bourgois, 2013) and shoulder extension/flexion test (Berg *et al.,* 1985) at a velocity of 60°/sec.

Statistical analysis

The Statistical Data Processing package (IBM SPSS Statistics Version 25) was used to determine the descriptive statistics (averages, standard deviations, minimum and maximum values) for each of the relevant variables to describe the isokinetic strength values of all players. A dependent t-test for statistical significant ($p \leq 0.05$) differences was done for the entire group on the differences for each player for the measured variables (D and ND of the upper and lower limbs) regarding bilateral differences.

Effect size (ES) was calculated for the entire group ($d = \frac{M1-M2}{s}$) and Cohen's effect size for practical significance as reported by Ellis and Steyn (2003) was used. Guidelines for effect size were: Small effect – d=0.2, medium effect – d=0.5 and large effect – d=0.8. The 90% Confident Interval (CI) and was qualitatively interpreted using the following thresholds: <0.19, trivial; 0.2 to 0.59, small; 0.6 to 0.1.19, medium; 1.2 to 1.99, large; 2.0 to 4.0, very large and; > 4, vast difference (Hopkins, 2009) to determine the likelihood that that the true value of the effect represents substantially beneficial or detrimental change. The smallest practically meaningful effect was considered 0.2 either positive or negative – with values implicating either the D (positive) or the ND (negative). Effects with CI's overlapping small positive or small negative effects were defined as unclear. Effect sizes that could be beneficial/ detrimental were either positively or negatively medium to nearly perfect with either the upper or lower limit of the 90% CI not exceeding a trivial ES (<0.19) on either side

RESULTS

Descriptive statistics for the variables used in this study are presented in Table 1.

The entire group of university level netball players showed a mean PT of 164.95±28.36Nm and 106.93±23.9Nm for knee extensor and flexor strength respectively with regards to the D limb, and 163.91±26.74Nm and 109.32±18.05Nm respectively for the ND limb. Where results were normalised for total body weight (TBW), the group showed a mean TBW of 2.28±0.38Nm/kg for knee extensor strength and 1.52±0.27Nm/kg for knee flexor strength of the D limb. The ND limb revealed a mean TBW in knee extensor strength of 2.27±0.39Nm/kg and 1.51±0.24Nm/kg for knee flexor strength.

The AG:AN percentage ratio for the H:Q revealed an average percentage ratio of 66.75±8.36% for the D limb and 67.68±12.68% for the ND limb. The knee flexor PT and the H:Q ratio showed higher values for the ND side, whereas the knee extensor PT, normalised for body weight extensor PT and normalised for body weight flexor PT values, was higher for the D side. The bilateral difference of the knee extensors showed an average of 9.39±7.63% deficit, where the D

knee had higher mean PT values. The knee flexors resulted in 9.73±6.24% deficit, with the ND knee having higher mean PT values.

Regarding the upper limbs, the shoulder extension/flexion isokinetic test results revealed that the shoulder extensor and flexor mean PT resulted in 63±8.38Nm and 44.45±7.35Nm respectively for the D limb and 59.27±7.67Nm and 42.32±6.12Nm for the ND limb. Normalised for total body weight the group showed a mean PT for the extensors and flexors of 0.87±0.11Nm/kg and 0.62±0.10Nm/kg for the D limb respectively. The ND limb showed a PT value of 0.82±0.11Nm/kg for the extensors and 0.59±0.09Nm/kg for the flexors respectively.

The AG:AN percentage ratio regarding the shoulder FLX:EXT revealed an average of 71.23±11.10% for the D limb and 72.32±11.21% for the ND limb. The shoulder extension mean PT, normalised for body weight extension PT, shoulder flexion mean PT and normalised for body weight flexion PT values, resulted in higher values for the D side. The shoulder FLX:EXT percentage ratio had higher values for the ND side. For the shoulder extension/flexion test, the bilateral differences for the extensor and flexors showed an average percentage of 8.68±6.55% deficit and 9.18±7.04% deficit respectively where the D shoulder had the greater mean PT values on both sides.

Table 1: Descriptive statistics of isokinetic variables for the dominant and non-dominant limbs of university level netball players.

	Dominant				Non-dominant			
Variable (N=44)	**Mean**	**Min**	**Max**	**Std. Dev.**	**Mean**	**Min**	**Max**	**Std. Dev.**
Age (yrs)	20.02	18.00	25.00	1.39				
Stature (cm)	175.68	148.00	191.00	7.17				
Mass (kg)	72.50	58.90	92.95	8.82				
Knee Extension/Flexion Isokinetic Variables:								
Extensor PT Value (Nm)	164.95	107.00	226.00	28.36	163.91	100.00	222.00	26.74
Extensor torque to body weight (TBW) (Nm/kg)	2.28	1.40	3.16	0.38	2.27	1.43	3.01	0.39
Flexors PT Value (Nm)	106.93	11.00	156.00	23.90	109.32	80.00	164.00	18.05
Flexors TBW (Nm/kg)	1.52	9.8	2.09	0.27	1.51	1.04	2.26	0.24
H:Q ratio (%)	66.75	47.00	82.00	8.36	67.68	49.00	119.00	12.68
Extensors deficit (%)	9.39	1.00	29.00	7.63				
Flexors deficit (%)	9.73	1.00	30.00	6.24				
Shoulder Extension/Flexion Isokinetic Variables:								
Extensor PT Value (Nm)	63.00	41.00	83.00	8.38	59.27	39.00	75.00	7.67
Extensor TBW (Nm/kg)	0.87	0.63	1.13	0.11	0.82	0.60	1.10	0.11
Flexors PT Value (Nm)	44.45	23.00	61.00	7.35	42.32	28.00	52.00	6.12
Flexors TBW (Nm/kg)	0.62	0.27	0.80	0.10	0.59	0.33	0.77	0.09
Shoulder FLX:EXT ratio (%)	71.23	40.00	92.00	11.10	72.32	50.00	103.00	11.21
Extensors deficit (%)	8.68	0.00	25.00	6.55				
Flexors deficit (%)	9.18	0.00	24.00	7.04				

Min: Minimum; Max: Maximum; Std Dev: Standard Deviation;

Table 2 represents the statistical and practical significant bilateral differences for the shoulder and knee extension/flexion tests at a testing velocity of 60°/sec. In Table 2, none of the isokinetic knee extension/flexion measurements showed a statistical or practical significant differences between the D and ND sides ($p>0.48$; $d<0.1$). The shoulder measurements (shoulder flexion/extension) showed a statistical ($p<0.02$) and practical ($d>0.28$) significant difference between the D and ND sides; the shoulder extensor variable showed a stronger statistical and practical significant difference ($p=0.00$; $d=0.44$) than the shoulder flexors ($p=0.01$; $d=0.29$). The shoulder FLX:EXT percentage ratio showed no statistical or practical significant difference between the D and ND side ($p=0.55$; $d=0.10$).

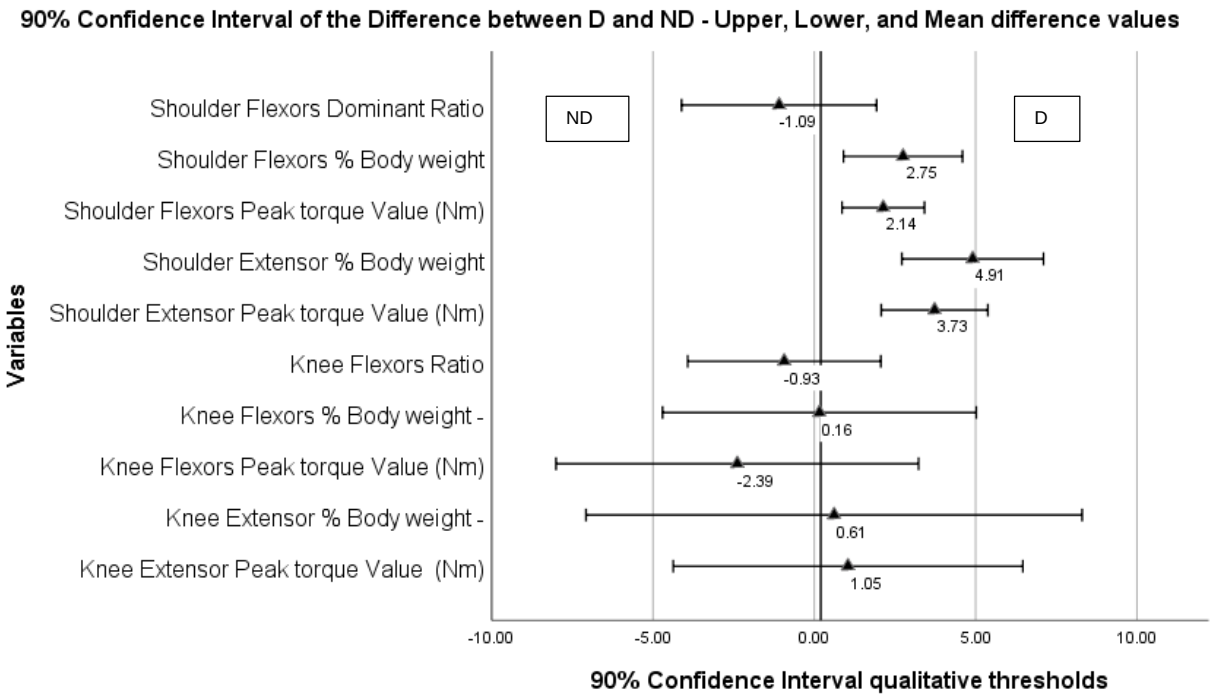

Figure 1: **HI- LOW BAR PLOT OF 90% CI OF THE MEAN DIFFERENCE BETWEEN THE D AND ND SIDES OF THE BODY WITH REGARDS TO THE MEASUREMENTS TAKEN WITH A REFERENCE OF -0.2 TO 0.2 TO INDICATE TRIVIAL TO UNCLEAR EFFECT SIZE OF MEASUREMENTS*.***

The high-low bar plot results of Figure 1 depict the mean differences between the D and ND sides size and the 90% CI for effect size upper and lower limits of each of the variables that did not indicate trivial to unclear effect size of measurements. From the results obtained, only the shoulder extensor PT (MD 3.73; 2.07 and 5.38), shoulder extensor normalised for total body weight (MD 4.91; 2.71 and 7.10), shoulder flexor PT (MD 2.14; 0.86 and 3.41) and shoulder flexor normalised for total body weight (MD 2.75; 0.91 and 4.59) medium to vast difference worthwhile effect size in favour of the D side. All other obtained results are considered unclear due to CI upper and lower limit exceeding the smallest positive and smallest negative effect of 0.2.

Table 2: Statistical and practical significant difference between dominant and non-dominant isokinetic variables of university level netball players.

Variable (N=44)	T-test for Dependent Samples				
	Mean Diff.	90% Confidence interval of the difference		Statistical sign diff (p)	Practical sign diff Effect size (d)
		Lower	Upper		
Knee Extensor PT Value (Nm)	1.05	-4.37	6.46	0.75	0.04
Knee Extensor TBW (Nm/kg)	0.61	-7.08	8.30	0.89	0.02
Knee Flexors PT Value (Nm)	-2.39	-8.00	3.23	0.48	0.10
Knee Flexors TBW (Nm/kg)	0.16	-4.70	5.02	0.96	0.01
H:Q ratio (%)	-0.93	-3.93	2.06	0.60	0.07
Shoulder Extensor PT Value (Nm)	3.73	2.07	5.38	0.00+	0.44**
Shoulder Extensor TBW (Nm/kg)	4.91	2.71	7.10	0.00+	0.45**
Shoulder Flexors PT Value (Nm)	2.14	0.86	3.41	0.01+	0.29*
Shoulder Flexors TBW (Nm/kg)	2.75	0.91	4.59	0.02+	0.28*
Shoulder FLX:EXT ratio (%)	-1.09	-4.12	1.93	0.55	0.10

** Small Practical Significance (d<0.3)*
*** Medium Practical Significance (d < 0.5)*
+ Statistical Significance level (p≤0.05)
Diff = Difference
Sign = Significant

DISCUSSION

The purpose of this study was to determine whether bilateral differences in isokinetic strength variables occur between the D and ND limbs of the upper and lower body. No statistical and practical significant differences were found in the knee extension/flexion isokinetic strength test, which is in correspondence with Kobayashi *et al*. (2013), who tested healthy male subjects. In their study the researchers found no statistical differences between the D and ND lower body regarding the knee extensors and flexors (p=0.25 and p=0.39 respectively), with only a small practical significant difference (d=0.22 and d=0.26 respectively) at a testing velocity 60°/sec. In our study the bilateral differences were less than 10% between the D and ND lower body, indicating that the netball players in this study had well muscle balance that was in line with the recommendations given in the literature (Knapik *et al*., 1991; Hewit *et al*., 2012; Xaverova *et al*., 2015; Fort-Vanmeerhaeghe *et al*., 2016).

The study of Kobayashi *et al*. (2013) contradict other studies (Phillips *et al*.,2000; Kong & Burns, 2010; Lanshammer & Riborn, 2011; Radio *et al.,* 2013) with regards to the knee extension/flexion isokinetic strength test. Statistical significant differences ($p<0.001$) were found between the D and ND limbs in the knee extension/flexion isokinetic test of female Swedish test subjects (Lanshammer & Ribom, 2011), male and female recreationally active athletes (Kong & Burns, 2010), random selected test subjects of different age groups and gender (Phillips *et al*., 2000), and in cadet basketball players (Radjo *et al*., 2013). The H:Q percentage ratio of the netball players was 66.75±8.36% for the D knee and 67.68±12.68% for the ND knee, which falls within the acceptable range between 50-80% at a testing velocity of 60°/sec (Hewett *et al*., 2008; Kong & Burns, 2010; Cheung *et al*., 2012). We attribute these findings to the specific strength training programmes and court training in which netball players take part, which involve unilateral as well as bilateral movements, or to the various passing and landing movements during netball training or a match. This further showed that the netball players from our study were in a well-balanced condition with regard to their lower limb bilateral differences and AG:AN muscular balance.

Even though the netball players showed statistical and practical significant isokinetic strength bilateral differences between the D and ND sides for the shoulder flexion/extension test, the D shoulder had greater values than the ND shoulder. The reason for this could be due to the asymmetric nature of shoulder movements in overhead throwing sport codes (Hadzic *et al*., 2014) where this relates to studies done on the isokinetic shoulder internal/external rotation test. Although limited studies was found on isokinetic strength for the shoulder flexion/extension movement, studies were included in the literature review that investigated isokinetic strength for the shoulder internal/external rotation movement. In a study on elite female handball players, researchers found that the players showed statistical significant differences between the D and ND shoulder for internal/external rotation ($p<0.05$) (Andrade *et al*., 2010). These findings correspond with the results of Markou and Vagenas (2006), who found statistical significant differences ($p=0.001$) between the D and ND sides for the shoulder internal-external rotation strength test in elite male volleyball players. Both of the above-mentioned studies showed that the D shoulder had higher values than the ND shoulder (Markou & Vagenas, 2006; Andrade *et al*., 2010). Regarding shoulder FLX:EXT ratio, these netball players showed a ratio of 71.23±11.10% for the D shoulder and 72.32±11.21% for the ND shoulder; these finding are similar to the shoulder FLX:EXT ratio of Berg *et al*. (1985), who found 81% and 77% for the left and right shoulders respectively (dominance was not recorded) at a testing velocity of 60°/sec. No recent studies investigated isokinetic strength for the shoulder flexion/extension movement were found for this literature review.

These bilateral differences observed for both the upper and lower body for our study's participants were less than the 10-15% recommended by various researchers (Knapik *et al*., 1991; Hewit *et*

al., 2012; Fort-Vanmeerhaeghe *et al*., 2016;) and may be due to the unilateral movements in various sporting codes (Cheung *et al*., 2012; Botton *et al*., 2013). The reason for the bilateral differences being larger in the upper body than in the lower body may be because the upper body is more exposed to unilateral movement in netball as well as upper body dominance and daily activity demands (Cheung *et al*., 2012; Botton *et al.*, 2013).

These findings support the notion that netball players tend to develop bilateral differences in the upper body according to the isokinetic shoulder extension/flexion strength test in response to the unilateral throwing demands of the game. The small amount of bilateral difference in the lower body may be due to well-designed training programmes that involve unilateral and bilateral movements, as well as the daily living activities of these netball players.

PRACTICAL APPLICATION

By investigating and monitoring the bilateral differences between the D and ND sides of university level netball players, alterations to strength training programs can be made to limit bilateral differences that will have a positive effect on performance as well as preventing possible injuries due to large bilateral differences. In the development of female university level netball players in South Africa, it is important to make this type of monitoring a high priority.

CONCLUSION

The aim of this study was to investigate the presence of upper and lower body isokinetic strength bilateral differences among university level netball players. In conclusion, the knee extension/flexion test showed no statistical and practical significant difference, but in contrast, the isokinetic variables for the shoulder extension/flexion test showed a statistical and practical significant differences between the D and ND sides, where the D side had the higher values. These results are worthwhile due to the CI at 90%. These findings may be the result of the greater unilateral demands of the upper body and the D arm being the preferred side during passing movements in netball.

Thus we conclude that university level netball players showed no bilateral difference between the D and ND side for the lower body, but these netball players showed significant bilateral differences in the upper body.

LIMITATIONS AND RECOMMENDATIONS

No control group was used in this study. It is therefore not possible to confirm that these bilateral differences in development are due to the actions of netball exclusively. These bilateral differences could be attributed to normal daily activities, where the D side is more likely to be used

than the ND side, especially in the upper body. Due to limited research studies using the isokinetic shoulder extension/flexion test, we will include the shoulder internal-external rotation test in future studies. It is recommended that more isokinetic strength tests over different joints, such as the wrist, ankle and hip, at different testing velocities, should be included in the research design so that more information can be obtained about the bilateral difference development in netball players, as well as other sport codes. Future studies will benefit from including these recommendations in planning so that better clarity can be achieved on bilateral differences in sport codes.

REFERENCES

ANDRADE, M.D.S.; FLEURY, A.M.; DE LIRA, C.A.B.; DUBAS, J.P. & DA SILVA, A.C. (2010). Profile of isokinetic eccentric-to-concentric strength ratios of shoulder rotator muscles in elite female team handball players. *Journal of Sport Sciences.* 28(7): 743-749.

BANDY, W.D. & MCLAUGHLIN, S. (1993). Intramachine and intermachine reliability for selected dynamic muscle performance test. *Journal of Orthopaedic & Sport Physical Therapy.* 18(5):6 09-613.

BERG, K.; BLANKE, D. & MILLER, M. (1985). Muscular fitness profile of female college basketball players. *The Journal of Orthopaedic and Sports Physical Therapy.* 7(2): 59–64.

BOONE, J. & BOURGOIS, J. (2013). Morphological and physiological profile of elite basketball players in Belgium. *International Journal of Sport Physiology and Performance.* 8(6): 630–638.

BOTTON, C.E.; RADAELLI, R.; WILHEM, E.N.; SILVA, B.G.C.; BROWN, L.E. & PINTO, R.S. (2013). Bilateral deficit between concentric and isometric muscle actions. *Isokinetics and Exercise Science.* 21(2): 161-165.

CHAN K.M.; MAFFULLI N.; KORKIA, P. & LI R.C.T. (1996). *Principles and practice of isokinetics in sports medicine and rehabilitation.* (1st ed.). Hong Kong: Williams & Wilkins.

CHANG, R.Y.; BRIFFA, K.N. & EDMONDSTON, S.J. (2013). Bone mineral density and body composition in elite female golf and netball players. *European Journal of Sport Science.* 13(2): 183-190.

CHEUNG, R.T.H.; SMITH, A.W. & WONG, D.P. (2012). H:Q Ratios and bilateral leg strength in college field and court sports players. *Journal of Human Kinetics.* 33: 63-71.

COOLS, A.M.; WITVROUW, E.E.; DECLERCQ, G.A.; VANDERSTRAENTEN, G.G. & CAMBIER, D.C. (2004). Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *British Journal of Sports Medicine,* 38(1): 64-68.

COOMBS, R. & CARBUTT, G. (2002). Development in the use of the hamstring/quadriceps ratio for the assessment of muscle balance. *Journal of Sport Science and Medicine*. 1(3): 56-62.

COREN, S. & PORAC, C. (1978). The validity and reliability of self-report items for the measurement of lateral preference. *British Journal of Psychology,* 69(2): 207-211.

CYBEX NORM™. (1996). *Testing and rehabilitation system user's guide*. New York, United States of America, Ronkonkoma: Cybex international, Inc.

DERVIŠEVIĆ, E. & HADŽIĆ, V. (2012). Quadriceps and hamstrings strength in team sports: Basketball, football and volleyball. *Isokinetics and Exercise Science.* 20(4): 293-300.

ELLIS, S.M. & STEYN, H.S. (2003). Practical significance (effect sizes) versus or in combination with statistical significance (p-values). *Management Dynamics*, 12(4): 51-56.

FORT-VANMEERHAEGHE, A., GUAL, G., ROMERO-RODRIQUES, D. & UNNITHAN, V. (2016). Lower limb neuromuscular asymmetry in volleyball and basketball players. *Journal of Human Kinetics*. 50(1): 135-143.

HADZIC, V.; SATTLER, T.; VESELKO, M.; MARKOVIC, G. & DERVISEVIC, E. (2014). Strength asymmetry of the shoulders in elite volleyball players. *Journal of Athletic Training.* 49(3): 338-344.

HETHERINTON, S.; KING. S.; VISENTIN. D. & BIRD. M.L. (2009). Kinematic and kinetic study of netball shoulder pass. *International Journal of Exercise Science.* 2(4): 243-253.

HEWETT, T.E.; MYER, G.D. & ZAZULAK, B.T. (2008). Hamstring to quadriceps peak torque ratios diverge between sexes with increasing isokinetic angular velocity. *Journal of Science and Medicine in Sport.* 11(5): 452-459.

HEWIT, J.K.; CRONIN, J.B. & HUME, P.A. (2012). Asymmetry in multi-directional jumping tasks. *Physical Therapy in Sport.* 13(4): 238-242.

JAKOBI, J.M. & CHILIBECK, P.D. (2001). Bilateral and unilateral contractions: Possible differences in maximal voluntary force. *Canadian Journal of Applied Physiology.* 26(1): 12-33.

KNAPIK, J.J.; BAUMAN C.L.; JONES, B.H.; HARRIS, J.M. & VAUGHAN L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *American Journal of Sports Medicine.* 19(1): 76-81.

KOBAYASHI, Y.; KUBO, J.; MATSUBAYASHI, T.; MATSUO, A.; KOBAYASHI, K., & ISHII, N. (2013). Relationship between bilateral differences in single-leg jumps and asymmetry in isokinetic knee strength. *Journal of Applied Biomechanics*. 29(1): 61-67.

KONG, P. W. & BURNS, S. F. (2010). Bilateral difference in hamstrings to quadriceps ratio in healthy males and females. *Physical Therapy in Sport*. 11(1): 12-17.

KOVAČEVIĆ, E.; ABAZOVIĆ, E.; BRADIĆ, J., & VRCIĆ, M. (2012). The predictive value of isokinetic assessment on the explosive strength of the lower extremities. *Homo Sporticus*. 14(1): 49-55.

LAND, H. & GORDON, S. (2011). What is normal isokinetic shoulder strength or strength ratios? A systematic review. *Isokinetics & Exercise Science*. 19(4): 231-241.

LANSHAMMER, K. & RIBOM E.L. (2011). Differences in muscle strength in dominant and non-dominant leg in females aged 20-39 – A population-based study. *Physical Therapy in Sport,* 12: 76-79.

LATEGAN, L. (2012). Differences in knee flexion and extension angles of peak torque between men and women. *Isokinetics & Exercise Science*, 20(2): 71-76.

MALERBA, J.L.; ADAMS, M.L.; HARRIS, B.A. & KERBS, D.E. (1993). Reliability of dynamic and isometric testing of shoulder external and internal rotators. *Journal of Orthopaedic and Sport Physical Therapy,* 18(4): 543–553.

MARKOU, S. & VAGENAS, G. (2006). Multivariate isokinetic asymmetry of the knee and shoulder in elite volleyball players. *European Journal of Sport Science.* 6(1): 71-80.

MAULDER, P.S. (2013). Dominant limb asymmetry associated with prospective injury occurrence. *South African Journal of Research in Sport, Physical Education and Recreation*. 35(1): 121-131.

M^{C}DONALD, A.C.; SAVOIE, S.M.; MULLA, D.M. & KEIR, P.J. (2018). Dynamic and static

shoulder strength relationship and predictive model. *Applied Ergonomics.* 67: 162-169.

MILLER, L.E.; NICKOLS-RICHARDSON, S.M.; WOOTTEN, D.F.; RAMP, W.K. & HERBERT, W.G. (2004). Relationships among bone mineral density, body composition and isokinetic strength in young women. *Clacified Tissue International.* 74(3): 229-235.

PAPADOPOULOS, G.; SIATRAS, H. & KELLIS. (2005). The effect of static and dynamic stretching exercises on the maximal isokinetic strength of the knee extensors and flexors. *Isokinetics and Exercise Science,* 13(4): 285-291.

PARCELL, A.C.; SAWYER, R.D.; TRICOLLI, V.A. & CHINEVERE, T.D. (2002). Minimum rest period for strength recovery during a common isokinetic testing protocol. *Medicine and Science in Sport & Exercise,* 34(6): 1018–1022.

PERRIN, D.H. (1993). *Isokinetic exercise and assessment*. (2nd ed.). Charlottesville, United States of America: Human Kinetics.

PHILLIPS, B.A.; LO, S.K. & MASTAGLIA, F.L. (2000). Isokinetic and isometric torque values using a Kin-Com dynamometer in normal subjects aged 20 – 69 years. *Isokinetics and Exercise Science*. 8(3): 147-159.

RADJO, I.; HANDZIC, O.; MANIC, G.; MAHMUTOVIC, I.; ALIC, H. & COLAKHODZIC, E. (2013). Asymmetry in strength of thigh muscles in basketball players. *Technics Technologies Education Management.* 8(2): 723-728.

ROSENE, J.M.; FOGARTY, T.D. & MAHAFFEY, B.L. (2001). Isokinetic hamstrings:quadriceps ratios in intercollegiate athletes. *Journal of Athletic Training.* 36(4): 378-383.

SOH, K.G.; HUSAIN, R. & SOH, K.L. (2006). Fitness profile among Malaysian netball players. *Journal of Physical Education & Recreation (Hong Kong).* 12(2): 40-44.

STASOFT INC, (2013). StatSoft. *Statistica data analysis software system, version 8*. Available at: http://www.statsoft.com/.

TERBLANCHE, E. & VENTER, R.E. (2009). The effect of backward training on the speed, agility and power of netball players. *South African Journal for Research in Sport, Physical Education and Recreation.* 31(2):135-145.

THOMAS, C.; COMFORT, P.; DOS'SANTOS, T. & JONES, P.A. (2017). Determining bilateral strength imbalances in youth basketball athletes. *International Journal of Sports Medicine.* 38(9): 683-390.

XAVEROVA, Z.; DRINBERGER, J.; LEHNERT, M.; BELKA J.; WAGNER, H. & ORECHOVSKA, K. (2015). Isokinetic strength profile of elite female handball players. *Journal of Human Kinetics.* 49(1): 257-266.

CHAPTER 5 -
SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

In this final chapter a brief summary of the study is given per chapter and the conclusion of the study is stated. This chapter also mentions limitations, makes recommendations based on this study and provides information for future studies.

5.2 SUMMARY

The purpose of this study was firstly to determine if there exist significant bilateral differences between anthropometric measurements of the dominant (D) and non-dominant (ND) limbs. Secondly, to determine whether significant bilateral differences occurred in isokinetic strength variables between D and ND limbs. All these measurements were done on the upper and lower limbs of university level netball players.

Chapter 1 provided a brief summary of the problem underlying the research question, objectives and hypothesis of this study and included the structure of this dissertation.

Chapter 2 consisted of a literature review titled: "*Bilateral differences in anthropometric measurements and isokinetic strength variables of netball players and various other sport codes*". The purpose of the literature review was firstly to describe the bilateral differences found in anthropometric measures of netball and other sport codes pertaining to unilateral movements, since research on bilateral differences in university level netball players is limited, and secondly to investigate bilateral differences in isokinetic strength variables such as peak torque (PT), percentage deficits and agonist/antagonist percentage ratio (AG:AN) of netball and other sport codes that rely mainly on unilateral movements.

Most activities in daily living and sport actions, which include throwing actions, are seen as unilateral movement. Executing a movement from a unilateral base-support refers to a weight-bearing movement supported by one limb, whereas bilateral movements are performed with weight evenly distributed between both limbs. From the literature review in Chapter 2, it is clear that netball players favour unilateral movement patterns such as throwing, passing, catching, jumping and landing. Unilateral movement may lead to the possibility of bilateral differences in anthropometric and strength variables in the upper and lower body between the D and ND limbs of netball players.

Asymmetry is defined as lack of equality or equivalence between parts/segments or lack of symmetry, and refers to the difference between the left and right sides of the body. The literature review reveals research into bilateral differences as an investigation to determine whether a difference exists between bilateral limbs; asymmetry also indicates that the difference between the limbs is remarkable.

Anthropometric profiles are important when considering potential for success in the performance of sport and provide coaches and sport professionals with the required information about the current state of the athlete's body composition (during the different phases of training). Previous anthropometric studies on netball players focused on the percentage body fat and the somatotype, but limited research could be found on bilateral differences that led to asymmetry in anthropometric measurement of netball players. From research in different sporting codes that predominantly use unilateral movements, it is evident that an adaptation to certain anthropometrical measurements does occur. Research studies have found a positive correlation between upper limb dominance and the hypertrophy of the distal humerus of inactive female subjects.

The repeated use of the D limb in unilateral sporting codes has a major influence on asymmetrical development and therefore the assessment of bilateral differences between limbs is of great importance. The performance of netball players is influenced by muscular strength, which is therefore an important characteristic of the general physical condition. Peak torque is the most common variable representing the strength of a muscle group during a movement and can be standardised to body weight. When bilateral muscle strength measurements are taken, it is recommended that the strength of muscle groups compared should not differ greatly. Bilateral strength differences may have an undesirable effect on performance and differences higher than 10-15% in muscle strength between the D and ND limbs need immediate attention. Not only do bilateral differences exist in muscle strength values, but also between the percentage ratios of the agonist and antagonist muscle groups at the joint of the D and ND limbs. Agonist and antagonist muscle ratios of athletes participating in different sport codes at similar competing levels may depend on the specific demands of the sport. Several studies have reported AG:AN values ranging from 50% to 80%, but no consensus could be found, and the general acceptance for AG:AN is set at 60%. Throughout the literature review chapter, there are indications of different isokinetic strength asymmetries for active and inactive subjects, as well as for athletes in different sport codes. It is also known that there are contradictions in the literature and limited research has been done on netball.

The bilateral difference is an occurrence that deserves attention because it demonstrates that the type of movement used (bilateral or unilateral) can have an effect on bilateral isokinetic muscle

strength. Unilateral movements are regularly used in sport and in conditioning programmes in which exercises are performed. This should be taken into consideration when planning a training programme, not only as a form of variation, but also as a way to increase training adaptation, especially for athletes who focus on unilateral movements. To achieve a more specific training approach, better understanding of bilateral differences and their interaction with sport performance is required.

The first article (Chapter 3), which was titled: *"Upper and lower body bilateral differences in anthropometric measurements of university level netball players",* was compiled according to the guidelines of The South African Journal for Research in Sport, Physical Education and Recreation. The purpose of the study was to determine the presence of upper as well as lower body bilateral differences in anthropometric measurements among university level netball players. Forty-four female players of a university in the North West province, with an average age of 20.2±1.4 years, stature of 175.7±7.2cm and body mass of 72.5±8.8kg, were tested. The results showed that the measurement of the D biceps skinfold, confirmed with the 90% Confident Interval (CI), had the largest bilateral difference and supported the statistical and practical significant difference. Limited studies found bilateral differences in anthropometrics, supporting the occurrence of bilateral development in other sport codes. These findings shows that netball players tend not to develop bilateral differences in body composition, owing to the demands of the sport and their unilateral movements. Thus we conclude that university level netball players show some marginally significant difference between the D and ND side.

Chapter 4 contains the second article, titled: "*Bilateral differences in upper and lower body isokinetic strength of university level netball players",* which was compiled according to the guidelines of The South African Journal for Research in Sport, Physical Education and Recreation. The aim of this article was to determine the presence of upper as well as lower body bilateral strength differences in isokinetic strength among university level netball players. Forty-four female players of a university in the North West province, with an average age of 20.2±1.4 years, stature of 175.7±7.2cm and body mass of 72.5±8.8kg, were tested. The results showed that there were no statistical or practical significant differences between the D and ND lower limbs in the isokinetic knee strength test. In contrast to these findings, in the upper body, shoulder measurements showed a statistical and practical significant difference between the D and ND sides, with the D shoulder being the stronger upper limb. The shoulder extensor mean PT showed a stronger statistical and practical significant difference than the shoulder flexors, even though the shoulder flexion/extension percentage ratio showed no statistical or practical significant differences between the D and ND sides, confirmed with the 90% CI. It is seen that university level netball players show a more significant difference between the D and ND sides in the upper body than in the lower body. These findings are an indication that netball players tend to develop

bilateral differences between D and ND limbs in the upper body owing to the demands of the sport and their unilateral movements, but exhibit less bilateral difference in the lower body.

5.3 CONCLUSION

The conclusions drawn from the research results are presented in accordance with the set hypotheses found in Chapter 1.

HYPOTHESIS 1: “Statistical significant differences between the D and ND limbs (upper and lower body) will occur, with the D limb presenting smaller anthropometric values for skinfold measurements, and larger girths and bone breadths measurements for university level netball players.” Statistical and practical significance difference was found for the biceps skinfold ($p=0.000$, $d=0.46$). This hypothesis is partially accepted, as small significant (statistical and practical) bilateral differences were found only for the biceps skinfold.

HYPOTHESIS 2: “Statistical significant differences between the D and ND limbs (upper and lower body) will occur and the D limbs will present greater PT values and better agonist/antagonist muscle ratio percentage for university level netball players.” No statistical or practical significant differences between the D and ND isokinetic knee strength ($p>0.48$; $d<0.1$) where found. In contrast, shoulder measurements showed a statistical ($p<0.02$) and practical ($d>0.28$) significant difference between the D and ND side. The shoulder extensor variable showed a stronger statistical and practical significant difference ($p=0.00$; $d=0.44$) than the shoulder flexors ($p=0.01$; $d=0.29$), even though the shoulder flexion-extension ratio showed no statistical or practical significant difference between the D and ND side ($p=0.55$; $d=0.10$). This hypothesis is partially accepted, as significant (statistical and practical) bilateral differences were found for the upper body where the D limbs present greater PT.

In conclusion, these findings support the hypothesis that netball players tend to develop bilateral differences between D and ND limbs. Regarding the anthropometric measurements, only the biceps skinfold showed statistical significant difference between the D and ND side where the D upper limb showed lower values. For the isokinetic strength, only the upper body showed statistical and practical significant difference, where the D surpassed the ND upper limb’s variables. These findings are due to the demands of the netball and its unilateral movements such as repeated throwing action of the D side as well as the netball players’ preference to land on ND lower limb when receiving the ball during netball games. Thus, we conclude that university level netball players showed significant differences between the D and ND side in the upper body.

5.4 LIMITATIONS AND RECOMMENDATIONS

This study provides information on the anthropometrical and isokinetic strength profiles, as well as evidence of bilateral difference in development of university level netball players. The study provides significant insight into the field of study for university level netball players with regard to bilateral differences. However, it has certain shortcomings that need to be addressed and taken into consideration when interpreting the results:

Firstly, no control group was used in the study; it is therefore impossible to confirm that the anthropometric and isokinetic asymmetric development or bilateral differences are the result of the actions of participation in netball or whether daily habits and other recreational activities contributed to this. These bilateral differences could be attributed to normal daily activities where the D side is more likely to be used than the ND side. The sample size could also have been larger for more validity in the study, which can therefore not be generalised to the whole of the country or the world. It is recommended that different university sites be included in future studies for better demographic representation of South Africa.

Secondly, only two joints were tested for isokinetic strength to determine bilateral differences. It is recommended that more isokinetic strength tests over different joints, such as the wrist, ankle and hip, could be included in the research design so that more information can be obtained about the bilateral difference development in netball players. Functional ratios of eccentric antagonist to concentric agonist muscular strength can add value to the functional demand of explosive power sport and should be included in future studies.

Thirdly, different playing levels and positions have different training programmes and schedules. Investigating the effect of different playing levels and/or positions may give a good indication of bilateral development of the D versus the ND limbs.

Fourthly, the rotator cuff muscle, which is primarily involved in the throwing mechanism (although the netball throwing mechanism differs from other throwing) may also give a good indication of bilateral development of the D versus the ND shoulder.

Lastly, it is recommended to correlate the player injury data and history with bilateral differences due to all the measurement ranges being within the 10-15% difference norm. We will then not specifically condition unilateral differences but if these values (even in range) causes injuries, then this will help give a better understanding to coaches and conditioning experts on how to address this in training.

Future studies can take these recommendations into account.

5.5 FUTURE RESEARCH

The findings of this study contributed to the field of study by providing evident report that netball players of the North West University showed upper body bilateral differences. The bilateral difference status of university level netball players was not known and this study provided vital information regarding bilateral differences in anthropometric measures as well as isokinetic strength values of these players.

The testing population and combination of anthropometric data with isokinetic data in university level netball players make this a unique study in South Africa. Further research on a larger sample size and different levels of competition can add value to investigate the presence of bilateral differences or the appearance of asymmetry in netball players. Understanding the demands of netball and the ways in which netball players adapt, can help sport scientists and coaches adjust training so that netball players will not develop large bilateral differences between D and ND limbs. Large bilateral differences may result in long-term pathologies later in life or impede performance. Future research can also compare functional testing versus isokinetic testing to see whether a correlation exists in these parameters.

ANNEXURE A – METHODOLOGY

Methodology

1. Literature review

The following search engines and databases was used to conduct the research:

- EBSCOHost
- Google Scholar
- Science Direct
- Sport Discus
- SabiNet

These electronic search engines and databases were used to search using the following keywords: Asymmetry in sport, bilateral differences, anthropometry, isokinetic strength and netball.

1.2. Empirical investigation

1.2.1 Study design

The study followed an experimental test design with convenience sampling.

1.2.2. Participants

A group of 44 female university level netball players at a university in the North West province was participating in the study (age between 18 and 26). Only players who provide voluntary consent was allowed to participate in this study. Approval from the university's department of sport, coaches and managers influenced the players' participation. The players was tested during the in-season phase of their periodization cycle.

The following inclusion criteria was applied for study participation:

- Participants must be female;
- Participants must be between the ages of 18 and 26 years;
- Participants must be involved in netball at university level;
- Participants must participate in formal games at university level;
- Participants must train at least three times a week;
- Participants must be free of any injuries at the time of testing; and must be injury free for 3 months; and
- Only participants who provided voluntary consent was allowed to participate in this study.

Furthermore, players who adhered to the following guidelines was allowed to participate in this

study:

- Participants who did not eat prior to the anthropometric testing sessions (Maughan & Sherriffs, 2004:921);
- Participant who did not drink alcohol or coffee 12 hours prior to the testing sessions (Wilmore *et al*., 2008:360;363); and
- Participant who did not train hard before testing session (Stewart *et al.,* 2011:51).

The following exclusion criteria was applied for study participation (Cybex Norm™, 1996:15):

- All participants not adhering to the above-mentioned criteria will be excluded from the study, as well as
- Participants who had any injuries (neck and upper thoracic problems);
- Participants who had any cardiovascular and or respiratory problems;
- Participants who were pregnant;
- Participants who had recent surgery (particularly eye surgery); and
- Participants who had recent illness such as cold or flu which may cause general weakness.

Risk for participants:

Participants might have experienced physical discomfort and exhaustion during the physical (isokinetic) assessments as it was required of them to perform the physical tests with maximal effort. Participants performed these tests before and therefore know what to expect. Participants had receive sufficient rest between trials and different assessments to ensure effective recovery after every maximal effort and thus give participants the opportunity to perform to their maximal effort each time. All monitor and safety measurements were in place.

1.2.3. Procedure

A week prior to testing, an information session was held for the participants explaining the purpose of the study and the procedures involved in the testing that was done. Before the start of experimental period the group was approached by an independent person whom explained the research study to the players in full. The independent person took responsibly of the informed consent form for the reason that the researcher had no influence on the decision of the participant. The group was approached at their training courts before a training session where the coach was present. During this time the informed consent forms was handed out. The players did not have to sign the forms at once and are allowed to take the forms home and asses all possible implications. The forms were only required one week after they have received them before the experimental period. The independent person reminded the players that participation is entirely voluntary. The consent NWU Ethics Committee: Ethics Application Form 9 form thoroughly explains the process of the research study and what will be expected from the participant as well

as the risks involved. The participants will had the opportunity to ask questions during the debriefing session and contact the researcher if any further questions arised. Sufficient time (one week) was allowed to read through and sign the consent in their own privacy if they agree to participate in the study. After a week, the forms was collected by the independent person at the same training courts before a training session where the coach was present. The informed consent form asked if the data collected may be used for research purposes. The consent form was valid for the duration of the experimental period. The participants was under no obligation to participate in the research study and was allowed to withdraw at any time during the tests.

Player's acceptance to join the study as participant was not announced. In no manner were players in direct contact with one another in the research environment. Time slots provided the researcher with enough time to ensure that players were not in the testing environment at the same time.

The informed consent was in English and although this is not the first language of the participants they should be proficient in English as they are all registered students at the university. English was also the language of communication. The use of English has been motivated by assessing the target group and all participants are currently students at a university in the North West province and are educated in both Afrikaans and English.

It was is not anticipated that the involved coach were present during the research study. If the coach wanted to be present during data collection, it was anticipated that her presence would encourage good performance from the participating player.

On the first day of testing, the participants underwent measurements to determine a full anthropometrical profile. After the anthropometric testing, limb dominance was performed by self-declaration. Later the same day isokinetic strength testing for the upper and lower limb was done on a schedule that accommodates the participants' daily routine (before participating in any form of exercise that day). The project was running for a time frame of two weeks to accommodate all the players where players must do the anthropometry (early morning) and the isokinetic (after breakfast for the remain of the day in time slots).

1.2.4. Measuring instruments and equipment

1.2.4.1. *General information questionnaire*

The netball players' personal information was collected by means of the above-mentioned questionnaire (Annexure B). The netball players' ages, dominant side (upper and lower body), training habits, injury history, competing levels and best performance was be obtained by means of this questionnaire.

1.2.4.2. *Anthropometric measurements*

The anthropometric measurements was executed early in the morning, before breakfast and training and approximately took 25 minutes. All anthropometric measurements was taken according to the International Society of Advancement of Kinanthropometry (ISAK) protocol (Stewart *et al*., 2011:50) by a level II ISAK accredited anthropometrist. The female field worker was present during the measurement to protect the researcher. Stature, body mass, eight skinfolds, six girths, five segments lengths and four bone breadths was measured on the dominant and non-dominant sides of each player. Table 1 consists of the anthropometric measurements. All players was measured in a private room. Two sets of measurements on both sides was taken for each bilateral variable, of which the mean value will be used for further analysis.

Players did wear minimal clothing (short and a crop top) to retrieve accurate data, and for this reason the anthropometrist was of same the gender. The measurements and equipment that was used are also listed in Table 1. Something to eat was provided after these measurements.

Table 1: Anthropometric measurements and equipment

Basic Measurements	Skinfolds **(Harpenden skinfold caliper - mm)**	Girths **(Anthropometric tape - cm)**	Segments lengths **(Segmometer - cm)**	Bone Breadths **(Bone caliper - cm)**
Body Mass (scale - kg)	Biceps skinfold	Relaxed upper arm girth	Acromial-radial length	Bi-epicodylar humerus breadth
Stature (stadiometer - m)	Triceps skinfold	Flexed upper arm girth	Radial-stylion length	Bi-styloid breath
	Subscapular skinfold	Forearm girth	Midstylion-dactylion length	Bi-epicondylar femur breadth
	Iliac crest skinfold	Wrist girth	Trochanterion-tibial lateral length	Bi-malleolus breadth
	Supraspinal skinfold	Mid-thigh girth	Tibial lateral height	
	Abdominal skinfold	Calf girth		
	Thigh skinfold			
	Medial calf skinfold			

1.2.4.3. *Limb Dominance Testing*

Limb dominance was determined to compare the D side with the ND side to investigate the bilateral differences. Limb dominance was determined by self-declaration for upper and lower limb. Coren and Porac (1978:209) reported that self-declaration was found to have a 97.7% agreement with task performance (kicking a ball) and a 96% test-retest agreement. Blackburn and Knüsel (2006:378) stated that previous studies have linked self-professed (stronger hand when preforming certain task such as throwing a ball) for the upper limbs with the hypertrophy of the distal humerus.

1.2.4.4. *Isokinetic Strength Tests*

An isokinetic dynamometer (Cybex Norm™, 1996) was used for testing isokinetic strength. The software that was used is the Humac 2014 and the Cybex was calibrated prior to the testing sessions. The calibration was done as indicated by the calibration protocol (Cybex Norm™, 1996). The testing consisted of knee flexion and extension protocol at a speed of 60°/sec for concentric movement (Boone & Bourgois, 2013:632; Dervišević & Hadžić, 2012:294; Miller *et al.,* 2004:230) and a shoulder flexion and extension (supine) protocol at a speed of 60°/sec for concentric movement (Berg *et al.,* 1985:59).

Isokinetic testing was done individually on time slots of 35 minutes that suited the player the best. Only the research team and the player was present at the testing opportunity. Before the isokinetic strength testing, each player performed a warm-up session. All participants followed the same order of testing by starting with the lower limbs. The warm-up for the lower limbs consisted of five minutes cycling on a stationary ergometer of low intensity (75 Watts) (Lategan, 2012:72), and specific dynamic stretches (Papadopoulos *et al.,* 2005:287). All participants followed the same order of testing by starting with the lower limbs, with sufficient rest after the first part of the test. The upper body warm-up consisted of two minutes sub-maximal intensity rowing on an upper body ergometer (Malerba *et al.,* 1993:545), shoulders rolls, wall push-ups and specific dynamic stretches for the upper limbs (Cools *et al.*, 2004:65).

Each netball player was be positioned according to the directions of the specific protocol (Cybex Norm™, 1996) being used for the different joints that was tested. A familiarization set was done prior to the formal test of the knee and shoulder and will consist of two (2) submaximal concentric contractions, after which the player rested for 60 seconds (Parcell *et al*., 2002:1021), followed by the maximal concentric contraction test, which consists of five (5) repetitions for the knee flexion - extension (Boone & Bourgois, 2013:632; Dervišević & Hadžić, 2012:294; Miller *et al.,* 2004:230) and shoulder flexion - extension (Berg *et al.,* 1985:59) at the velocity of 60°/sec.

1.3. Ethical considerations

Ethical approval for this study was obtained from the Human Research Ethics Committee of the Faculty of Health Science at the North-West University (Annexure F - NWU-00359-15-A1). In order to gather data from the netball players at the North-West University, a project letter was sent to the head of NWU- Netball explaining the purpose of the study and asking for permission (Annexure - D). Informed consent (Annexure C) and general information (Annexure B) forms was given to the netball players to explain the purpose of the study so that players could give consent to take part in the study. In addition, the players had to complete the informed consent form as an indication that they were willing to voluntarily participate in the study and that they understand that they had the right to withdraw from the study at any time. Players did not have to give a

reason for refusing to take part, and withdrawal would not have any negative consequences for them whatsoever. The netball players' information and results will be kept private. Data for the research project will be kept safe and secure by locking hard copies (anthropometric measurements) in locked cupboards in the researcher's office and the electronic data (isokinetic strength variables) will be password protected. Only the research team will have access to the data. Hard copies will be stored for a minimum of 7 years where after it will be destroyed by shredding the hard copies and formatting the electronic copy. This data will not leave the country.

The benefits for participants, coaches and the sport scientist was outlined, and the coach and sport scientist was given feedback on the findings in the form of a group report. The participants was provided with an individual report regarding their performance scores on all assessments. Each participant was asked consent to share their results with their coach – the coach received all individual reports as well as a group summary report compiled of participants that have given consent to see their results . In line with the recommendations of Ethical Approaches, participants was treated fairly and was not be forced to participate in the study. The data gathered was analysed in aggregate and responses was not ascribed to any respondent. No remuneration was given to the netball players for their participation in the study and the benefits from the study outweighed the risks.

1.4. Statistical analysis

The Statistical Consultation Service of the North-West University determined the statistical methods and procedures for the analyses of the research data. The Statistical Data Processing package (Statsoft Inc., 2013) and IBM SPSS Statistics (version 21.0.0.0), which was available on the North-West University network, was used to process the data.

Firstly, descriptive statistics (averages, standard deviations, minimum and maximum values) for each of the relevant variables was calculated to determine the anthropometric profiles of the players. A dependent t-test for statistical significance ($p \leq 0.05$) was done for the total group for the different variables (D and ND of the upper and lower limbs) regarding the bilateral differences. Effect size was calculated for the total group ($d = \frac{M1-M2}{s}$) and Cohen's effect size for practical significance as reported by Ellis and Steyn (2003:54) was used. See guidelines for effect size in table 2. The technical error of measurement (TEM) will be calculated making use of the formula of Pederson and Gore (1996:85) (Perini *et al.,* 2005:87). The 90% CI and was qualitatively interpreted using the following thresholds: <0.19, trivial; 0.2 to 0.59, small; 0.6 to 0.1.19, medium; 1.2 to 1.99, large; 2.0 to 4.0, very large and; > 4, nearly perfect (Hopkins, 2009) to determine the likelihood that that the true value of the effect represents substantially beneficial or detrimental change. The smallest practically meaningful effect was considered 0.2 either positive or negative – with values implicating either the D (positive) or the ND (negative). Effects with CIs overlapping

small positive or small negative effects were defined as unclear. Effect sizes that could be beneficial/ detrimental were either positively or negatively medium to nearly perfect with either the upper or lower limit of the 90%CI not exceeding a trivial ES (<0.19) on either side

Table 2: Cohen's guidelines for effect size.

Small effect	Medium effect	Large effect
d = 0.2	*d* = 0.5	*d* = 0.8

Secondly, descriptive statistics (averages, standard deviations, minimum and maximum values) for each of the relevant variables was firstly be calculated to describe the isokinetic strength values of the players. A dependent t-test for statistical significance ($p \leq 0.05$) were then done for the total group on the difference for each player for the different variables (D and ND of the upper and lower limbs) regarding the bilateral differences. Effect size was calculated for the total group ($d = \frac{M1-M2}{s}$) and Cohen's effect size for practical significance as reported by Ellis and Steyn (2003:54) will be used. The 90% CI and was qualitatively interpreted using the following thresholds: <0.19, trivial; 0.2 to 0.59, small; 0.6 to 0.1.19, medium; 1.2 to 1.99, large; 2.0 to 4.0, very large and; > 4, nearly perfect (Hopkins, 2009) to determine the likelihood that that the true value of the effect represents substantially beneficial or detrimental change. The smallest practically meaningful effect was considered 0.2 either positive or negative – with values implicating either the D (positive) or the ND (negative). Effects with CIs overlapping small positive or small negative effects were defined as unclear. Effect sizes that could be beneficial/ detrimental were either positively or negatively medium to nearly perfect with either the upper or lower limit of the 90%CI not exceeding a trivial ES (<0.19) on either side.

REFERENCES

Berg, K., Blanke, D. & Miller, M. 1985. Muscular fitness profile of female college basketball players. *The journal of orthopaedic and sports physical therapy,* 7(2): 59–64.

Blackburn, A. & Knüsel, C.J. 2006. Hand dominance and bilateral asymmetry of the epicondylar breadth of the humerus. *Current anthropology,* 47(2): 377-382.

Boone, J. & Bourgois, J. 2013. Morphological and physiological profile of elite basketball players in Belgium. *International journal of sport physiology and performance,* 8(6): 630–638.

Cools, A.M., Witvrouw, E.E., Declercq, G.A., Vanderstraenten, G.G. & Cambier, D.C. 2004. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *British journal of sports medicine,* 38(1): 64-68.

Coren, S & Porac, C. 1978. The validity and reliability of self-report items for the measurement of lateral preference. *British journal of psychology,* 69(2): 207-211.

Cybex Norm™ Testing and rehabilitation system user's guide. 1996. *Cybex international, Inc.* Ronkonkoma, New York – United States of America.

Dervišević, E. & Hadžić, V. 2012. Quadriceps and Hamstrings strength in team sports: Basketball, football and volleyball. *Isokinetics and exercise science,* 20(4): 293-300.

Ellis, S.M. & Steyn, H.S. 2003. Practical significance (effect sizes) versus or in combination with statistical significance (p-values). *Management dynamics*, 12(4): 51-56.

Lategan, L. 2012. Differences in knee flexion and extension angles of peak torque between men and women. *Isokinetics & exercise Science*, 20 (2): 71-76.

Malerba, J.L., Adams, M.L., Harris, B.A. & Kerbs, D.E. 1993. Reliability of dynamic and isometric testing of shoulder external and internal rotators. *Journal of orthopaedic and sport physical therapy,* 18(4): 543–553.

Maughan, R. & Sherriffs, S. 2004. Exercise in the heat: Challenges and opportunities. *Journal of sport sciences,* 22(10): 917-927.

Miller, L.E., Nickols-Richardson, S.M., Wootten, D.F., Ramp, W.K. & Herbert, W.G. 2004. Relationships among bone mineral density, Body Composition and Isokinetic strength in young women. *Calcified tissue international,* 74(3): 229-235.

Papadopoulos, G., Siatras, H. & Kellis. 2005. The effect of static and dynamic stretching exercises on the maximal isokinetic strength of the knee extensors and flexors. *Isokinetics and Exercise Science,* 13(4): 285-291.

Parcell, A.C., Sawyer, R.D., Tricolli, V.A. & Chinevere, T.D. 2002. Minimum rest period for strength recovery during a common isokinetic testing protocol. *Medicine and science in sport & exercise,* 34(6): 1018–1022.

Statsoft, Inc. 2013. STATISTICA (Data analysis software system), version 10. http://www.statsoft.com.

Stewart, A., Marfell-Jones, M., Olds, T. & De Ridder, H. 2011. International Standards for Anthropometric Assessment. *International society for the advancement of kinanthropometry.* ISAK New Zealand.

Wilmore, J.H., Costill, D.L. & Kenney, W.L. 2008. Physiology of sport and exercise. 4th ed. Champaign, IL: Human Kinetics.

ANNEXURE B – GENERAL INFORMATION QUESTIONNAIRE

General information questionnaire

Name: _____ **Surname:** _____

Contact no: _____

Sport information:

Team currently playing for:	u/19		u/21		Seniors		
	A	B	A	B	1	2	3
Playing position in current team:	GS	GA	WA	C	WD	GD	GK
Years of participation at university level:	0-3	4-6	7-10	10+			
Highest level played at school level:	Club	Provincial	National				
Highest level played at university level:	Club	Provincial	National				
Perceived Dominance: Upper limbs (Throwing hand)	Left	Right					
Perceived Dominance: Lower limbs (Kicking foot)	Left	Right					

Training information:

Please indicate how many sessions a week do you spend on training (1 - 7days).

	Days	Hours per day
Gym sessions per week:		
Court sessions per week:		
Other session (specify):		

Injury History:

Had any injuries in the last 6 months?	Yes			No		
If yes, which limb?	Shoulder	Elbow	Back/neck	Hip	Knee	Ankle
Specify injuries and treatment:						

Are you injury free? YES NO

You confirm that above mention information is correct.

Signature: _____ Date: _____

ANNEXURE C –INFORMED CONSENT FORM

Faculty of Health Sciences

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

INFORMED CONSENT FORM

Bilateral differences in anthropometric measurements and isokinetic strength variables of female university level netball players.

CONSENT TO BE A RESEARCH PARTICIPANT

We (Mrs. Kyra Duvenage, Dr Yolandi Willemse, Prof Hans de Ridder and Me Esti Kruger), from the North-West University, are working on a project to determine the asymmetrical isokinetic and anthropometry profile of university level netball players in the North West Province. Therefore we would like to invite you to give consent and participate in our study. Information about the study follows so that you can make an informed decision.

1. PURPOSE OF THE STUDY

The purpose of this study is to determine the bilateral differences of anthropometry measurements and isokinetic strength variables of university level netball players in the Nort West province – South Africa. You are being asked to participate in this study because of your status as a university level netball player in the North West province and your anthropometric and strength profiles are very valuable to us.

2. PROCEDURE

If you agree to be in this study you will expected to do all of the following:

- Complete a demographic general information questionnaire regarding your participation, training and injury history.
- Participate in anthropometrical measurements (8 skinfold measurements, 6 girth measurements, 5 segments lengths and 4 breath measurements on the dominant and non-dominant side of the body) to determine the bilateral differences in anthropometrical measurements. It is important to be dressed in minimal clothing such as a crop top and ski pants. This session will take about 25 minutes.

- On the same day (in the time slot chosen by you), participate in 2 different maximal isokinetic strength tests (knee concentric flexion–extension and shoulder flexion - extension for both the dominant and non-dominant limb). The machine that will be used is the Cybex Norm. You will be strapped to the chair during the test to isolate the muscles. It is important to wear training clothes and training shoes so that there is no movement restriction.

3. INCLUSION AND EXCLUSION CRITERIA

The following inclusion criteria was applied for study participation:

- Participants must be female;
- Participants must be between the ages of 18 and 26 years;
- Participants must be involved in netball at university level;
- Participants must participate in formal games at university level;
- Participants must train at least three times a week;
- Participants must be free of any injuries at the time of testing; and must be injury free for 3 months; and
- Only participants who provided voluntary consent was allowed to participate in this study.

Furthermore, players who adhered to the following guidelines was allowed to participate in this study:

- Participants who did not eat prior to the anthropometric testing sessions;
- Participant who did not drink alcohol or coffee 12 hours prior to the testing sessions; and
- Participant who did not train hard before testing session.

The following exclusion criteria was applied for study participation:

- All participants not adhering to the above-mentioned criteria will be excluded from the study, as well as
- Participants who had any injuries (neck and upper thoracic problems);
- Participants who had any cardiovascular and or respiratory problems;
- Participants who were pregnant;
- Participants who had recent surgery (particularly eye surgery); and
- Participants who had recent illness such as cold or flu which may cause general weakness.

4. RISKS/DISCOMFORTS

Some discomfort will be felt during these tests, especially when undergoing the anthropometrical testing. However, be assured that these tests will be conducted in a private room and the data

will be recorded by an accredited Kinanthropometrist of the same gender. You are more than welcome to bring a friend or chaperone to be with you during these tests. Discomfort can also be felt during the isokinetic strength testing, since the equipment tests the maximum strength you can produce during the movement. During these strength tests the equipment has stoppage points to ensure minimal risk of injury, and the strength is equal to the strength the participant moves against. A first aid (level 2) will be present during these tests.

Your name will never be made known and your data will be handled anonymous and confidential. No individual identifiers will be used in any publications resulting from this study and only the team of researchers will work with the information that you share. All sensitive information will be protected on a password-protected computer.
You have the right to voluntarily stop the testing at any moment when feeling uncomfortable.

5. BENEFITS

Among the direct benefits are that you and the coach will have access to the results by means of a feedback report, and this would give you a better understanding of your strength.

After this study it will be clear what the anthropometric and isokinetic strength bilateral difference profile of a university level netball player in the North West province looks like.

6. COSTS

There will be no cost to you as a result of your participation in this study.

7. PAYMENT

You will receive no payment for participation.

8. QUESTIONS

You are welcome to ask any questions to a member of the research team before you decide to give consent. You are also welcome to contact Mrs. Kyra Duvenage if you have any further questions concerning you consent at 018 285 2493.

9. FEEDBACK OF FINDINGS

The findings of the research will be shared with you if you are interested. You are welcome to contact us regarding the findings of the research. We will be sharing the findings with you as soon as it is available.

INFORMED CONSENT FORM

PARTICIPATION IN THIS RESEARCH IS VOLUNTARY.

You are free to decline to be in this study or to withdraw at any point even after you have signed the form to give consent without facing any consequences.

Should you be willing to participate you are requested to sign below:

I _____ hereby voluntarily consent to participate in the above-mentioned study. I have not been coerced in any way to participate and I understand that I can withdraw at any time should I feel uncomfortable during the study. I also understand that my name will not be disclosed to anybody who is not part of the study and that the information will be kept confidential and not linked to my name at any stage. I also understand the possible benefits of participation and the possible risks and that someone will be available should I need further information.

_____	_____
Date	Signature of the participant
_____	_____
Date	Signature of the person obtaining consent

Original details: Carolien van Zyl(13210572) C:\Users\13210572\Documents\toets.docm
19 March 2014

ANNEXURE D – GATEKEEPERS LETTER

Faculty of Health Sciences

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

School for Biokinetics, Recreation and Sport Science

Dr Yolandi Willemse
Tel: +2718 299 1811
Fax: +2718 299 2022
Email: yolandi.willemse@nwu.ac.za

Dear Madam/Sir

RE: RESEARCH – A bilateral comparison in the anthropometric measurements and isokinetic strength variables of female university level netball players.

With this letter we request your permission and support to do a research project on university level netball players in the North West province.

Ms. Kyra Duvenage is a Masters-degree student in Sport Science at the Potchefstroom Campus of the North-West University. As part of an envisaged project to investigate this growing sport in our country, the aim is to conduct a research study to determine the asymmetrical profiles of university level netball players.

The recording of data will take place during the 2016 season. The testing will take place between March and May. All the players will undergo two separate tests. The first test will consist of *anthropometrical testing* for the dominant and non-dominant side (after declaring their dominant side). The second test (after a warm-up session) will be to measure *knee and shoulder isokinetic strength* on the Cybex at two one speed of 60°/sec (to determine power) for each joint (dominant and dominant limb). Each netball player will receive a time slot that fits into their daily programme. These tests will be done in the laboratory of the Institute for Sport Science and Development at the FNB High Performance Institute in Potchefstroom.

Despite the possible approval for the research project, each player and coach will also have to sign an informed consent form before the research can commence. No player will therefore be forced to participate in the project and the player can withdraw from the project at any time.

The handling of data will be done in accordance with the strict ethical rules related to confidentially. None of the information or data will be used or be made available to any other person or party except for explicit use in the research project. Individual feedback will be given to the players and the coach/sport scientist of the team will get feedback in a group report.

As there is little to no evidence-based research on the bilateral difference of the isokinetic and anthropometrical profiles of university level netball players, we believe it will be of great value for coaches and sport scientists. The results of this study could help coaches/sport scientists in designing more effective training programmes.

The following inclusion criteria will be applied for study participation:

- Participants must be female;
- Participants must be between the ages of 18 and 26 years;
- Participants must be involved in netball at university level;
- Participants must participate in formal games at university level;
- Participants must train at least three times a week;
- Participants must be free of any injuries at the time of testing; and must be injury free for 3 months;
- Only participants who provide voluntary consent will be allowed to participate in this study.

Furthermore, players who adhere to the following guidelines will be allowed to participate in this study:

- Participants who did not eat prior to the anthropometric testing sessions (Maughan & Sherriffs, 2004:921)
- Participant who did not drink alcohol or coffee 12 hours prior to the testing sessions (Wilmore *et al*., 2008:360;363);
- Participant who did not train hard before testing session (Stewart *et al.,* 2011:51).

The following exclusion criteria will be applied for study participation (Cybex Norm™, 1996:15):

- All participants not adhering to the above-mentioned criteria will be excluded from the study, as well as
- Participants who have any injuries (neck and upper thoracic problems);
- Participants who have/had any cardiovascular and or respiratory problems;
- Participants who are pregnant;
- Participants who have had recent surgery (particularly eye surgery); and
- Participants who have had recent illness such as cold or flu which may cause general weakness.

Yours sincerely

Dr. Yolandi Willemse
Project Leader

Kyra Duvenage
Masters Student

Please sign below to approve the study:

_____ _____

PUK Netball Manager Date

_____ _____

PUK Netball Coach Date

ANNEXURE E – AUTHOR GUIDELINES FOR: SOUTH AFRICAN JOURNAL FOR RESEARCH IN SPORT, PHYSICAL EDUCATION AND RECREATION

INFORMATION FOR AUTHORS

The *South African Journal for Research in Sport, Physical Education and Recreation* is published by Stellenbosch University. Contributions from the fields of Sport Science, Physical Education, Recreation/Leisure Studies, Exercise Science and Dance Studies will be considered for publication. The articles submitted will be administered by the appropriate Subject Review Editor and evaluated by two or more referees. The decision as to whether a particular article is to be published or not, rests with the Editorial Board.

SUBMISSION

Manuscripts that do not comply with the following requirements regarding process, style and format will not be handled.

Manuscripts should be typed with ***one and a half spacing*** in 12-point Times New Roman letter size for the text. All the text in tables and figures should be in 10-point Times New Roman font size. Please do not use *Calibri*. The original manuscript can be submitted by Email. The length may not exceed 20 pages (tables, figures, references, etc. included). The **page setup** (cm) must be in the following format:

MARGINS		**PAPER SIZE**	
Top:	3.56 cm	*Width*:	17.5 cm
Bottom:	1.78 cm	*Height*:	24.5 cm
Left:	2.11 cm		
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Gutter:	0.00 cm		
Header:	2.03 cm		
Footer:	0.89 cm		

Original manuscripts may be submitted in English or Afrikaans and should be sent to:

The Editor
South African Journal for Research in Sport, Physical Education and Recreation
Physical Activity, Sport and Recreation
North-West University, POTCHEFSTROOM
Republic of South Africa

Editorial Office
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CONDITIONS

Each manuscript must be accompanied by a ***covering letter*** in which the following is declared: (1) that the manuscript contains original research; (2) that the manuscript or parts of the manuscript has not been published elsewhere previously; (3) that the manuscript is not currently being presented elsewhere for publication; and (4) that all the authors have read and approved the manuscript. This signed declaration regarding the originality must accompany each manuscript.

Authors are also requested to name three/3 potential referees, of which one/1 must be an *international* referee (the Journal is not bound to use these referees). Complete information regarding the referees (name, surname, e-mail address and telephone numbers) must be provided in the cover letter.

We discourage the practice of parts of one study in different journals. Authors who submit a manuscript from a study of which some data have been or will be published elsewhere, must provide a strong justification in the accompanying letter to the Editor. The justification for not publishing all the data together in one paper must also be motivated in the covering letter.

The author should also ensure that the ***language*** of the manuscript has been ***edited*** thoroughly (English [UK]) by the time of submission. The name, address and telephone number of the person who did the language editing must be provided. Any expenses incurred by the Journal dealing with language editing will be added to the author's page fees.

The manuscript must have an ***ethical clearance number*** that was supplied by the authentic ethical committee of a specific institution. The process that was followed to obtain ethical clearance must be described in the manuscript under the heading, 'Ethical clearance'. No manuscript can be published without this declaration. Review articles do not need ethical clearance.

Any uncertainty regarding the ***statistical procedures*** that arise during the assessment of the manuscript will be referred to a local statistician. Any expenses incurred by the Journal dealing with statistical procedures will be added to the author's page fees.

PREPARATION OF MANUSCRIPT

Manuscripts must be presented in a format that is compatible with *Microsoft Word for Windows* (PC). Tables, all figures (illustrations, diagrams, etc.) and graphs are regarded as text and must be presented in a format that is compatible with ***Word*** and figures should be ***accessible*** to make any text corrections. Photographs must be presented in *jpg* format.

Original manuscripts must contain the following sections in the following sequence: Title page, Abstract, Introduction, Purpose of Research, Methodology, Results, Discussion, Practical application, Conclusions, Acknowledgements (if applicable) and References.

Title page

The first page of each manuscript should indicate the *title* in English and Afrikaans (will be translated for foreign authors), the *names* (title, first name in full and other initials, surname) of the author(s), the *telephone* numbers (work & home [& *mobile* for local authors]), *facsimile* number, *E-mail* address and the *field of study*. The ***complete mailing address*** and ***telephone numbers*** of the corresponding author and the institution (department, university, city, country) where the work was conducted should be provided in full. When more than one author and/or authors from various departments and institutions are involved, the [1]***author*(s)** must be numbered according to their [1]***department*(s)**. If any of the above-mentioned information should change during the review process, please inform the Subject Editor. A ***short title*** of not more than ***45 characters*** (including spaces), should be provided for use as a running heading.

Abstract

Each manuscript must be accompanied by an abstract of approximately 150-200 words in *English* and should be set on a *separate page* as a SINGLE paragraph (1.5 spacing). A list of three to seven ***key words*** in *English* is required for indexing purposes and they should be typed below the abstract. Articles in Afrikaans must include an ***additional*** extended ***summary*** (500-1000 words) in English. This summary must start on a new page (just before the reference list) and the English title of the article should be placed at the beginning.

Text

Start the text on a new page with the title of the article (centred and *without* the names of the authors). Follow the style of the most recent issue of the Journal regarding the use of headings and subheadings. Use only ***one line space*** after a paragraph. Only make use of ***section breaks*** and not ***page breaks***. The text, as well as the tables and figures, may not be in any other format than ***normal***. Thus, ***no style sheets*** may be used.

Tables and figures

Tables and figures should be numbered in *Arabic* numerals (1, 2, etc.). Tables require the heading at the *top,* while figures have the legend *below* and both are not included in the cells of the table/figure. ***Note:*** Use the decimal POINT (not the decimal comma). The site where the table or figure should be placed in the text must be indicated clearly in the manuscript. All tables and figures are to be placed *after the reference list* with each on a ***separate page***, always ending with a ***section break***. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

It is essential that tables/figures should be contained/fit within the page setup described earlier for this Journal. Portrait layout must be maintained for all tables/figures. Tables must use separate rows/columns (do not merge cells) for each item. Figures must be in ***Word*** and accessible to make corrections or changes within the figure where deemed necessary. Please ensure that the figures especially are of high quality for printing purposes. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

References

In the *text*, the Harvard method must be adopted by providing the author's surname and the date placed in parentheses. *For example:* Daly (1970); King and Loathes (1985); (Botha & Sonn, 2002); McGuines *et al.* (1986) or (Daly, 1970:80) where Daly is not part of the sentence and page number is added for a direct quotation. More than one reference must be arranged ***chronologically*** (Daly, 1970; King & Loathes, 1985). Note that *et al.* (italics) is used in the body of the text from the beginning when there are ***more than two authors***, but never in the list of references, where all authors must be provided.

List of references

Only the references cited in the text should be listed alphabetically according to surname (last name) of authors (uppercase) after the body of text under the heading, **REFERENCES** (uppercase) starting on a new page. In the case where the TITLE of an article, book, etc., is in any other language than English, the author must also provide an ***English translation*** of the title in parentheses (this applies to Afrikaans titles as well).

In the case of articles published in ***JOURNALS,*** references listed should include the surnames and initials (upper case) of ***all*** authors, the date of the publication in parentheses, the full title of the article, the full title of the journal (italics), the volume number, the series/issue number in parentheses (omitted only if the said journal does not use issue numbers), followed by a colon and a space with the first and last page numbers separated by a hyphen. The use of the correct punctuation is of importance.

If the reference is a ***BOOK,*** the surname (last name, upper case) and initials (without spaces) of the author or editor (Ed.) must be provided, followed by the date of publication in parentheses, the title of the book (italics) as given on the title page, the number of the edition (ed.) in parentheses, the city (and abbreviation for the state in the case of the USA OR the country) where published, followed by a colon, a space and the name of the publisher.

For a ***CHAPTER*** in a book, the page numbers of the chapter cited must be provided in parentheses (not italics) after the title of the book. For further details, authors should consult the most recent publication of this Journal for other examples.

If the reference is a ***THESIS*** (master's level) or ***DISSERTATION*** (doctoral level), italics is **not** used in the title as it is an unpublished work. Provide the name of the city, state/country, colon, university and department/faculty.

For ***ELECTRONIC SOURCES*****,** all references start with the same information that would be provided for a printed source (if available). The web page information follows the reference. It will usually contain the name of the author(s) (if known), year of publication or last revision, title of

complete work in inverted commas, title of web page in italics, Uniform Resource Locater (URL) or access path in text brackets (do not end the path statement with a full stop), full stop after the closing bracket and date of access, "Retrieved on 10 December 2015". See "How to cite information from the Internet and the Worldwide Web" at [http://www.apa.org/journals/webref.html] for specific examples. When citing a web site in the text, merely give the author and date. When reference is made to a specific statement (quotation) in the article/document and no page number is given, the word 'online' is used for citing in the text (e.g. Van der Merwe, 2010:online).

When referencing an article in a ***NEWSPAPER,*** the key word of the newspaper is typed in capitals, as this is how it will appear in the ***alphabetical listing*** of references, namely *The CAPE ARGUS* will appear under "C" or *Die BURGER* will appear under "B".

In the case of a paper presented in conference ***PROCEEDINGS***, the editors and the title of the proceedings, the page numbers of the article being referred to and the details of the congress (when and where it was held) and by whom the proceedings was published should be provided.

EXAMPLES OF STYLE OF FORMULATIONS FOR DIFFERENT REFERENCES

Journal

ZHENG, N.; BARRENTINE, S.W.; FLEISIG, G.S. & ANDREWS, J.R. (2008). Kinematic analysis of swing in pro and amateur golfer. *International Journal of Sports Medicine*, 29(6): 487-493.

Book

WEINBERG, R.S. & GOULD, D. (2011). *Foundations of sport and exercise psychology* (5th ed.). Champaign, IL: Human Kinetics.

Chapter in book

SCHNECK, C.M. (2010). Visual perception. In J. Case-Smith & J.C. O'Brian (Eds.), *Occupational therapy for children* (6th ed.) (pp. 373-403). Maryland Heights, MO: Mosby.

Thesis/Dissertation

SURUJLAL, J. (2004). Human resources management of professional sports coaches in South Africa. Unpublished doctoral dissertation. Johannesburg, South Africa: Rand Afrikaans University.

Proceedings of a conference

HARDMAN, K. & MARSHALL, J. (2001). Worldwide survey on the state and status of physical education in schools. In G. Doll-Tepper & D. Scoretz (Eds.), *World summit on physical education* (pp. 15-37). Proceedings of the "World Summit on Physical Education", 3-5 November 1999. Berlin, Germany: International Council of Sport Science and Physical Education (ICSSPE).

Personal communication/correspondence/interview

BOUKES, P.B. (2015). Personal communication from the Acting Director of Sport at the Nelson Mandela Metropolitan University, Port Elizabeth on 27 February 2015.

JACOBS, L. (2015). Personal interview with the Spokesperson of UNICEF, 25 August, Pretoria.

Newspaper

CAPE ARGUS, *The* (1997). 25 March, p.5.

Electronic source

DINOFFER, J. (2011). “Activities to build balance”. *Prevent child obesity 101.* Hyperlink: [http: //www.preventchildobesity101.com/Activities/BalanceActivities.php]. Retrieved on 20 November 2012.

ADMINISTRATION

If authors honour the rules and specifications for the submission of manuscripts, unnecessary delays would be avoided. Requesting ‘copy right’ concerning figures or photographs is the responsibility of the authors and should be indicated. A manuscript that does not meet the requirements, as set out above, will be returned to the author without being evaluated. A subject specialist Editor administers and coordinates the assessment of the referees and provides the final recommendation.

The corresponding author will receive a complimentary copy of the Journal and five reprints of the article that could be shared with the co-authors. The original manuscripts and illustrations will be discarded one month after publication unless a request is received to return the original to the corresponding author. A page fee of South African **R300** per page is payable on receipt of a statement issued by the Editor.

ANNEXURE F – ETHICS CERTIFICATE

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: http://www.nwu.ac.za

Institutional Research Ethics Regulatory Committee
Tel +27 18 299 4849
Email Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF PROJECT

Based on approval by **Health Research Ethics Committee (HREC)**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: **Bilateral differences in anthropometric measurements and isokinetic strength variables of female university level netball players.**

Project Leader/Supervisor: **Dr Y Willemse**
Student: **K Wolmarans**

Ethics number:

N	W	U	-	0	0	3	5	9	-	1	5	-	A	1
Institution				Project Number						Year			Status	

Status: S = Submission, R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Approval date: 2016-03-01 **Expiry date:** 2016-11-20 **Risk** **Medium**

Special conditions of the approval (if any):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the HREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HREC. Ethics approval is required BEFORE approval can be obtained from these authorities.
- Any further information and any report templates is obtainable from Carolien van Zyl at Carolien.VanZyl@nwu.ac.za.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC and HREC:*
  - *annually (or as otherwise requested) on the progress of the project, and upon completion of the project*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
  - *Annually a number of projects may be randomly selected for an external audit.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the HREC and NWU-IRERC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-IRERC and HREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the NWU-IRERC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA Du Plessis

Digitally signed by Prof LA Du Plessis
DN: cn=Prof LA Du Plessis, o=North-West University, ou=Campus Rector, email=Linda.DuPlessis@nwu.ac.za, c=ZA
Date: 2016.03.09 09:54:20 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

ANNEXURE G – PROOF OF LANGUAGE EDITING

M.B. BRADLEY

P.O. Box 37326
Faerie Glen
Pretoria 0043

072 369 5149

DECLARATION ON EDITING

Student: K. Duvenage	**Date**: 2018/11/05

Document submitted for editing
Dissertation: **Bilateral differences in anthropometric measurements and isokinetic strength variables of female university level netball players**
The above dissertation was submitted to me for language editing, which was completed on 2 November 2018. M.B. BRADLEY (MA) - Language editor