The Effects of Balance Training on Dynamic Balance Capabilities in the Elite Australian Rules Footballer.

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ABSTRACT

The ability to balance on a single leg is a major requirement for many skills in Australian Rules football. At present there is no other research evaluating dynamic single leg balance ability of an elite AFL team over an entire football season. Therefore this study investigated changes in dynamic single leg balance capabilities of an elite Australian Rules football team with the introduction of a comprehensive balance training program, over an entire 44 week pre-season and competition season. Single leg balance was tested before, during (10 weeks) and after the training program (44 weeks), by placing a wobble board placed on top of a force plate and measuring various parameters of centre of pressure (COP) movement. The balance training program included wobble board training and other balance exercises, and core stability exercises. These were performed in addition to normal football training. Of an initial eligible group of twenty-five players, fourteen subjects remained free of football-related injuries and completed all three tests and the full training program, with a mean (SD) age of 22 (2.4) years, body mass 88 kg (8) and height 188.9 cm (7).

To establish which COP parameters were reliable for assessment of the balance training program, reliability testing found the following $ICC_{\mathbf{3,1}}$ above 0.800, Mean COP medial lateral (ML) displacement (0.841), COP displacement (0.837), COP ML path SD (0.843) and COP 95% confidence ellipse area (0.852). Results of the training study found a significant reduction in measures of centre of pressure sway after 10 weeks and 44 weeks: COP 95% confidence ellipse area (p=0.00), Mean COP ML displacement

(p=0.01), COP displacement (p=0.00) and COP ML path SD (p=0.00) all decreased ($p<0.05$).

Percentage improvement ranged from approximately 13% to 25% (Mean COP ML displacement and COP 95% confidence ellipse area, respectively) for pre-test compared to post test one after 10 weeks of training, and from approximately 27% to 50% (Mean COP ML displacement and COP 95% confidence ellipse area, respectively) for pre-test compared to post test two at 44 weeks.

This research shows that balance training incorporating wobble board and core stability exercises, in addition to normal football training, can improve balance over an entire elite Australian Rules football season.

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CHAPTER 1 INTRODUCTION

Australian Rules footballI requires a variety of motor skills including the maintenance of balance while running, evading, kicking, marking, tackling and changing direction. Balance, the ability to maintain a stable position over a base of support is an important component of a human's single leg stance ability (Matsuda *et al.* 2008; Paterno *et al.* 2004). Typically balance forms the basis for motor skills, from simple to more challenging, in sport (Anderson and Behm, 2005; Davlin, 2004). Balance in football, dynamic in nature, requires single limb control in order to complete functional tasks during football such as kicking, jumping, landing, tackling, running and evading. Dynamic balance requires a combination of both ankle and knee proprioception and core stability in order to maintain an upright posture. Balance incorporates the visual, vestibular and somatosensory input from afferent and efferent control strategies (Matsuda *et al.* 2008; Simoneau *et al.* 1995). Proprioception is a specialized sensory modality that includes the sensation of joint and muscle movement and known as kinesthesia and joint position sense (Lephart *et al.* 1997). Core stability is the body's ability to maintain dynamic equilibrium of the trunk as a result of internal or external disturbance (Zanzulak *et al.* 2008). Research supports the proposition that, physiologically muscle and joints have proprioceptive qualities, but there has been limited applied research on the practical applications of balance training for elite team sport athletes (Lephart *et al.* 1997).

While balance studies have assessed the impact of balance training in reducing injury reoccurrence, there is less research investigating whether balance training including wobble board and core stability exercises, improves balance in the elite able bodied

Australian Rules footballer. While balance studies have included balance training typically using wobble boards, core stability exercises are also an important component of developing dynamic balance. The trunk or ‘core’ provides an anatomical stable base for movement of distal segments (Kibler *et al.* 2006). The current research was undertaken as there is no research investigating whether single leg dynamic balance can be maintained or indeed enhanced in an elite Australian Rules football team completing balance training within a complete Australian Rules football season.

Studies of dynamic balance have typically assessed balance through the intervention of balance training over 4-10 weeks (Guillou *et al.* 2007; Hertel *et al.* 2006; Jonsson *et al.* 2004; Tropp and Askling, 1988; Tropp *et al.* 1984; Verhagen *et al.* 2005). This research tested balance at ten and 44 weeks after initiation of a balance intervention program incorporating wobble board and core stability training. It is hypothesized that balance training will improve single leg dynamic balance in the elite Australian Rules footballer. The purpose of this research is to investigate whether dynamic single leg balance can be improved throughout a full season (44 weeks) of an elite Australian Rules footballer. The study will assess balance from the pre-season period continuing through to the in-season training program. The training program includes both balance training and trunk strengthening exercises in order to improve single limb dynamic balance. This will be assessed by testing sway by centre of pressure displacement of single limb stability while on a force plate.

CHAPTER 2 REVIEW OF LITERATURE

2.1 Physiology of balance

Optimal balance in an upright posture is a fundamental requirement in sport (Anderson and Behm, 2005). While the title of this research is, “The effects of balance training on the dynamic balance capabilities in the elite Australian Rules footballer”, ‘balance’ incorporates both *balance* training on wobble boards for example and *core stability* training such as completing Swiss ball exercises. Therefore, in reference to all sections both balance and core stability training will be delineated. Core stability is the body’s ability to maintain dynamic equilibrium of the trunk as a result of internal or external disturbance (Zanzulak *et al.* 2008). The ability of the trunk to control the pelvis and legs resulting in optimum force and motion to the terminal segment (Kibler *et al.* 2006). Unstable environments such as standing on one leg require sensory and motor feedback systems in an attempt to reduce increased postural sway (Nardone and Schieppati, 1988). To execute constant corrections required to resist the destabilising effect of gravity and the perturbations while running and jumping, the central and peripheral nervous system must determine the position of the body’s centre of gravity relative to the gravitational force and the base of support, and then execute coordinated movements to correct any centre of gravity deviations. The physiological systems and processes used in balance are visual, vestibular and somatosensory input, and muscle and joint proprioception (Diener and Dichgans, 1988). Balance relies on the combination of all of these systems.

This section discusses the physiology of balance while biomechanical aspects of balance are discussed in section 2.2.

2.1.2 Proprioception

The central and peripheral mechanisms for sensing balance collectively make up the proprioceptive system. Somatosensory input is derived from peripheral afferents via contact forces and motions between the feet and the support surface. The sensory system provides information to the central nervous system (CNS) about the position of peripheral limbs. The central nervous system receives messages from proprioceptors found in the joints, muscle and tendons and sends messages along efferent pathways back to muscles of the peripheral limbs and balance adjustments are made.

Proprioception can be defined as a specialised variation of the sensory modality of touch that encompasses the sensation of joint movement (kinaesthesia) and joint position sense (Lephart *et al.* 1997). Figure 2.1 shows the various components of the proprioception system. Proprioceptors include muscle and joint receptors, which assist in sensing joint angles.

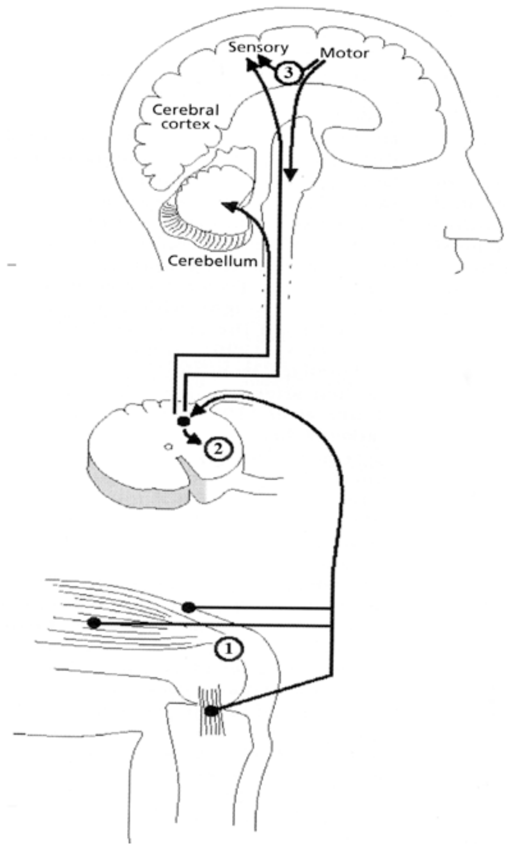


Figure 2.1: Components of proprioceptive system.

1.Muscle/tendon, ligament and skin specialised proprioceptors (mechanoreceptors). Receptors in the CNS, brain stem, spinal reflexes and cognitive programming send messages to muscle to alter length or tension.

2. Somatosensory pathways.

3. Motor, sensory, balance, visual components of the proprioceptive system where areas of the brain receive messages from mechanoreceptors (Adapted from Stillman, 2002).

Joint proprioceptors are specialised receptors found in tendons and ligaments providing information about the length and tension of these structures within a joint (Stillman, 2002).

Muscles have specialised receptors that sense varied features of the state of muscle. Muscle spindles respond to stretch of muscle fibres provide the brain with information on limb position and muscle length (Ashton-Miller *et al.* 2001; Gandevia, 1996). While a muscle lengthens, the spindle discharges increases directly proportional to the length of muscle (Winter *et al*. 2005). The spindle firing rate and muscle length provides information to the CNS on limb position (Winter *et al.* 2005).

It has been suggested that muscle receptors rather than joint receptors are more important receptors in position sense. Winter *et al.* (2005) carried out experiments to ascertain whether in the absence of vision, position sense at the human forearm occurs through input from muscle spindles in muscle. They found that when arms were placed in front of a subject without vision, the subject was still able to accurately determine position of the arm.

Gandevia *et al*. (2006) provided further evidence of the role of muscle in position sense. During complete limb paralysis a subject’s position sense was not reliant on joint receptors but rather muscle receptors to identify position sense.

2.1.3 Physiology of balance control

Postural adjustments are flexible synergies in which muscles used in a specific task are fine tuned to task-specific activities (Allum *et al.* 1993; Diener and Dichgans, 1988). The proprioceptive, vision and vestibular systems are working in coordination between muscle, sensory receptors and the central nervous system (CNS) brain and spinal cord. The somatosensory and visual inputs are more sensitive to body sway than the vestibular system. The primary role of vestibular system is to signal balance disturbance through independent and precise control of head and eye positions. The cerebellum, the location of balance control in the brain, provides subconscious regulation of balance and movement (Stillman, 2002). Balance adjustments, either reactive or proactive, are characterised by coordinated motor patterns at a number of joints. In response to the visual, vestibular and somatosensory inputs, efferent impulses to muscles to maintain balance involve motions of the ankle, knee and hip joints, which require coordinated actions of ankle, thigh and lower trunk muscles.

2.2 Biomechanics of balance

2.2.1 Mechanism of balance

Balance, the ability to maintain the body's position over its base of support, is fundamental in single leg stance (Berg *et al.* 1989; Matsuda *et al.* 2008). In order to understand the mechanisms of balance it is important to know how gravity affects the body. The base of support is the area under the foot. To balance, the body's centre of gravity must be maintained vertically over the base of support.

When this is met, the person can resist the destabilising influence of gravity and actively move the centre of gravity (COG). If the COG is positioned outside the base of support, additional external support is required to prevent a fall.

The origin of the ground reaction vector at floor level (beneath the feet) is commonly known as the centre of pressure (COP). This is the average location of pressure between the foot and ground, which varies around the surface of the bottom of the foot when balancing. This provides an objective measurement of total force, the result of gravity and forces from body segments (Tropp and Odenrick, 1985). The COP in the human body under static and more significantly under dynamic balance is the result of forces through joints and muscles. The COP can provide an indication of sway on the force platform. Sway has been defined as the deviation from the mean centre of pressure of movement the foot (Guskiewicz and Perrin, 1996).

2.2.2 Core stability

The sport of Australian Rules football involves tackling, bumping, pushing and shepherding, marking, kicking and handballing. All of these skills require dynamic balance through core stability, allowing the body to maintain dynamic equilibrium of the trunk, which is reliant upon the motor system in order to realign after these types of external perturbations. As mentioned, balance requires the centre of gravity to fall within the base of support in order to maintain upright balance. In order to maintain balance while moving, the trunk or ‘core’ provides a structural support mechanism reducing the potential to fall. The core includes muscles of the trunk and vertebrae. Training the core muscles in an unstable environment has been found to produce greater activation during exercise.

The core stability muscles that stabilize the pelvis and vertebral column are primarily the abdominal musculature anteriorly, including transversus abdominus, internal and external obliques and rectus abdominus, and back muscles posteriorly including the erector spinae, quadratus lumborum and multifidus. The central nervous system activates these muscular stabilisers of the abdominal wall anteriorly and back muscles posteriorly providing a stable platform for movement of the lower limbs (Zanzulak *et al.* 2008).

Kavcic *et al.* (2004) completed a study of core muscles in order to find their role in stabilisation. Fourteen trunk electromyographic (EMG) electrodes were attached to subjects while completing seven stabilisation exercises such as a abdominal curl, side bridge, sitting on a Swiss ball and four point kneeling with contralateral arm and leg extension. Results found that larger movement required larger muscles to stabilise the spine, while smaller intersegmental spinal muscles were prioritised during subtle movement. Kavcic *et al.* (2004) concluded that if the aim is to train stability then it is important to include exercises, which incorporate many muscles rather than targeting a few specific muscles.

Vezina and Hubley-Kozey (2000) evaluated muscle activation patterns in three abdominal and two trunk extensor muscles during pelvic tilt and abdominal hollowing while lifting the leg up to 90 degrees. Subjects completed three exercises, which were repeated five times at five muscle sites while surface EMG was recorded. It was found that all five muscles were activated during the movements tested. Results also found that the three exercises tested resulted in similar patterns of muscle activation. Results of this study suggest that a variety of exercises can activate core muscles, which can be beneficial in developing core stability.

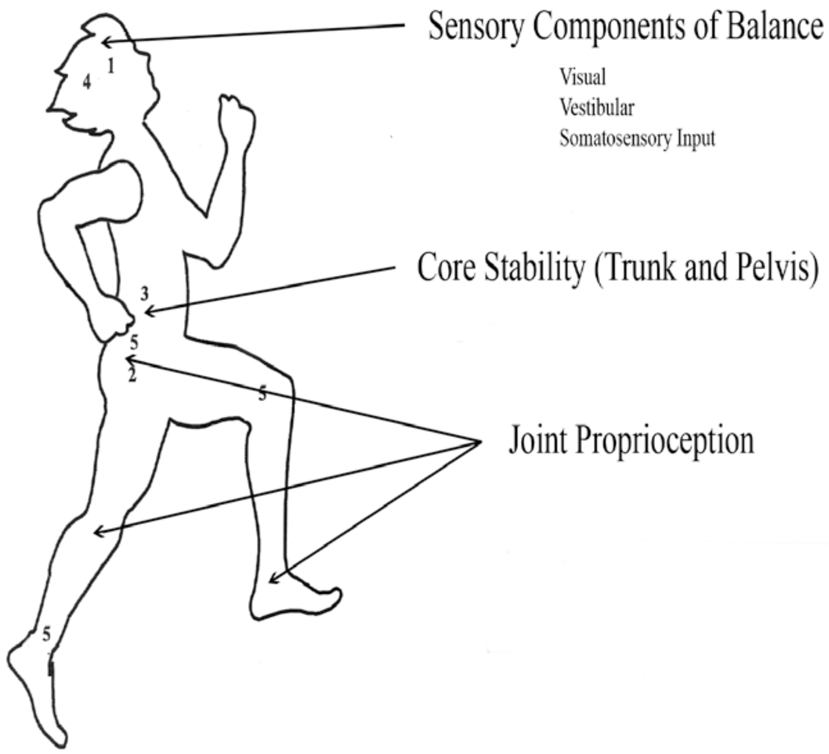
Many different devices have been used in core stability training, such as Swiss balls and wobble boards providing a more demanding balance task in an unstable environment. Such devices promote imbalance, as COP sway may project the centre of mass outside the base of support of the device, such as a wobble board (Behm *et al.* 2003; Behm *et al.* 2010 a). Behm *et al.* (2005) compared core muscle EMG activity with unstable and unilateral exercises. Instability exercises included exercises on a Swiss ball. Stable exercises included those that provide a firm base of support such as a weights bench to complete a shoulder press. Subjects had no history of any low back pain. EMG surface electrodes were attached to upper lumbar, lumbar erectors and abdominals during exercises. Subjects completed exercises on the Swiss ball with a 3 second hold when contracting trunk muscles. Other exercises were tested including a side bridge and prone static position lying on the Swiss ball with one arm extended in front and the opposite side leg extended, and the foot in contact with the ground. Swiss ball exercises resulted in greater EMG activity compared to exercises on a stable base, in the lower abdominal stabilising muscle. The unstable exercises resulted in significantly greater activation of erector spinae than did stable exercises. Instability exercises produced greater muscle activation than stable exercises. Training on unstable surfaces with resistance exercise increases activation of core musculature compared with the same exercise under stable conditions (Anderson and Behm, 2004; Marshall and Murphy, 2006; Santana *et al.* 2007; Vera-Garcia *et al.* 2007).

Collectively, muscles of the trunk co-contract to increase core stability. Lee *et al.* (2006) further concluded that co-contraction of trunk musculature increased trunk stiffness. Bogduk *et al.* (1992) and McGill, (1996) state that it is the alignment of the trunk muscles, which allow for large compressive forces, which assist in stiffening the spine. 'Active' stiffness is the ratio of resisting muscle force to length change in a contracting muscle. Active trunk stiffness is thus associated with active muscle contraction of trunk muscles. The core muscles with the most ability to produce force and therefore stabilize the spine are the erector spinae and quadratus lumborum posteriorly and rectus abdominus anteriorly (Behm *et al.* 2010 b).

In summary, core stability includes training the muscles of the trunk and vertebrae. Muscle stiffness underpins the production of core stability. Dynamic balance activities such as using Swiss balls and wobble boards can increase activation of core muscles as opposed to more stable exercise. However, dynamic balance not only requires core stability, but as discussed previously, proprioceptive qualities of the physiological and biomechanical systems of the body. Figure 2.2 summarises the combined influence of the central nervous system, proprioceptive role of muscle, joint and trunk control in allowing dynamic balance. It is the combined qualities that enable balance once external perturbation has occurred.

2.3 Balance assessment

Many studies have assessed dynamic balance using single leg stance (Guillou *et al.* 2007; Hertel *et al.* 2006; Jonsson *et al.* 2004; Mattacola and Lloyd, 1997; Tropp *et al.* 1984; Tropp and Askling, 1988; Verhagen *et al.* 2005). There are a variety of methods for testing balance. Previously, balance has been assessed using the Romberg procedure (Winter, 1991). The test involved the subject standing on flat



1. Vestibular system – responsible for signalling balance disturbances through visual feedback from the eyes and auditory feedback through the inner ear.

2. Muscle balance – muscle spindles providing proprioceptive feedback.

3. Deep postural stabilising musculature such as transversus anteriorly and multifidus posteriorly, causes a rise in intra-abdominal providing core stability.

4. Cerebellum – sensing the position of the centre of gravity and the base of support.

5.Proprioceptors – muscle spindle and joint receptors, which communicate with the brain, interpreting joint position and modifying movement in order to remain balanced.

Figure 2.2: Diagram illustrating the influence of proprioceptive, core stabilisation and central nervous system qualities on dynamic balance.

ground, unilaterally with eyes either open or closed. Assessment was based on the time subjects could maintain balance by not hitting the ground with their foot.

Measuring COP excursion on force platforms has been used extensively as a more sophisticated and accurate means of assessing balance (Bernier and Perrin, 1998; Gauffin *et al.* 1988; Hughes *et al.* 1995; Karlsson and Frykberg, 2000; Le Clair and Riach, 1996; Lord and Castell, 1994; Matsuda *et al.* 2008; Popovic *et al.* 2000; Riach *et al.* 1992; Tropp and Askling, 1988; Verhagen *et al.* 2005). The subject stands on the force platform, and any movements in an anterior-posterior (AP) and medial-lateral (ML) direction are recorded as changes in ground reaction forces and moments (collected on the computer via the analog to digital converter), from which the centre of pressure is calculated. Centre of pressure (COP) is the point location of the vertical ground reaction force vector at floor surface level. It represents a weighted average of all the forces over the surface of the area in contact with the ground (Winter, 1995). If only one foot is on the ground the COP lies within that foot. If both feet are on the ground and weight is evenly distributed then the COP lies between the two feet. Increased movement of the ankle, such as plantarflexion, moves the COP anteriorly and inversion moves the COP laterally.

Measurement of balance by using Centre of Pressure (COP) in both the medial-lateral (ML) direction and anterior-posterior (AP) direction has been a common specific measure assessed in balance testing (Hoffman and Payne, 1995; Hrysomallis, 2008; Le Clair and Riach, 1996; Paillard *et al.* 2006; Verhagen *et al.* 2005). Other studies have measured balance COP path length, which is the total length of the COP path covered (Ageberg *et al*. 2003; Gauffin *et al*. 1988).

COP ML path standard deviation (SD) from average in the medial-lateral and anterior-posterior direction has also been used as a measure of COP during balance testing (Hrysomallis, 2008; Le Clair and Riach, 1996; Paterno *et al.* 2004. Gauffin *et al.* (1988); Gerbino, (2006); Paillard *et al.* (2006) Salvati *et al.* (2009) and Tropp and Askling, (1988), have all measured COP ellipse area as the test parameter in their respective studies, that is, the ellipse that best fits the scatter of x and y co-ordinates. COP ellipse represents the 95% of COP points distributed. Figure 2.3 presents a typical COP 95% confidence ellipse area graph measuring a subject's single leg balance.

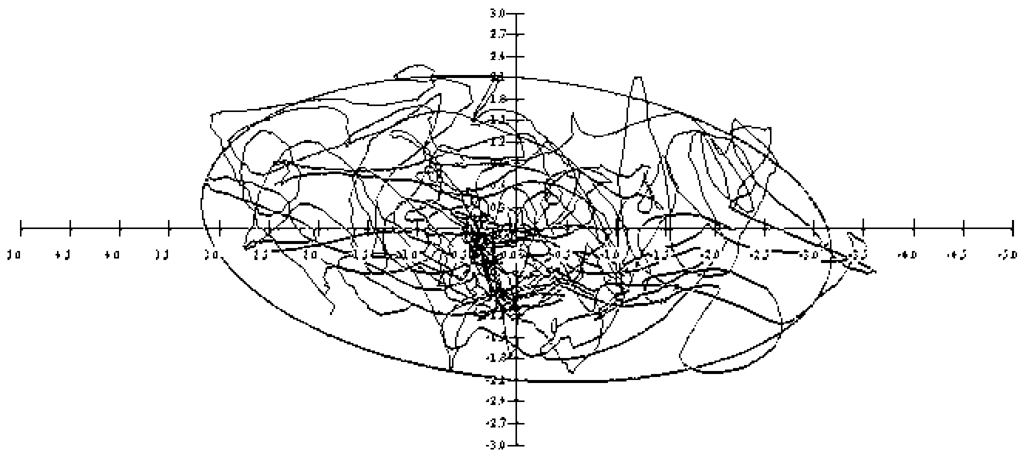


Figure 2.3: Typical COP 95% confidence ellipse area.

2.3.2 Reliability of COP balance parameters used in balance training studies.

While there are numerous studies conducted assessing the balance ability of athletes on a force plate, very few studies have completed a reliability study of test parameters, particularly prior to commencement of a training study. Reliability analysis compares parameters over two test periods without any training intervention, to ascertain whether the scores are consistent. The Intraclass Correlation Coefficient (ICC) is the quantitative association between the initial test and retest scores; a value 1.0 indicates perfect agreement and 0.0 indicates no agreement. According to Shrout and Fleiss, (1979) an ICC of >0.80 represents acceptable reliability.

Hrysomallis, (2008) completed a reliability test of COP movement in the ML direction. This was the only research in Australian Rules football including balance testing among athletes that included a reliability analysis of test parameters prior to completing the main study. The reliability study involved measuring maximum COP excursion in ML direction in single leg balance on a foam mat placed on top of the force plate for 20 seconds. Subjects included elite Australian Rules footballers, tested on two consecutive days. The reliability study resulted in an ICC of 0.80.

Paterno *et al*. (2004) completed a reliability study of the total, AP and ML parameters on a Biodex balance testing apparatus. Reliability results revealed ICC's of 0.72 for total balance, 0.77 for AP balance and 0.81 for ML balance. However, only five subjects were used in the reliability study.

Ageberg *et al.* (2003) assessed the reliability of COP path displacement used in evaluating single limb balance in healthy subjects. Forty-two subjects were tested one week apart and revealed no difference between test-retest. The results reveal that this test is reliable when testing COP of balance in single limb stance amongst health subjects with ICC values between 0.79-0.95.

LeClair and Riach, (1996) evaluated the reliability of the test duration of force plate testing to determine optimum test duration. Twenty-five subjects 19-32 years were tested between 10, 20, 30, 45 and 60 seconds in relation to six COP outcome measures. The test included a strain gauge force platform to measure ground reaction forces. Parameters such as COP AP and ML maximum excursion and COP average velocity were used to evaluate the effect of the test duration in determining reliable COP measurements. Results found that test duration affects the possible COP outcome measures. Optimum test-retest reliability was found for both 20 and 30 second tests.

Jonsson *et al.* (2004) investigated single leg balance in healthy young adults by AP, ML and vertical ground reaction forces measured on a force plate. They found that the test must be longer than 5 seconds. The initial 5 seconds of balance increases movement and therefore postural readjustment in the subject.

2.3.3 Force plate balance testing using different surfaces

Assessing balance has included using a variety of surfaces designed to be sensitive enough to elicit change. Various studies have utilised surfaces such as foam mats, tilt boards on the platform, seesaw apparatus such as stabilometry, tilting platforms and movable platforms.

Unstable surfaces as opposed to stable surfaces perhaps provide a more dynamic method of evaluating balance similar to the dynamic nature of balance used in sport.

Gerbino *et al.* (2006) and Hrysomallis, (2008) both used a foam surface to increase the difficulty of the balance test in the elite athlete population. The reasoning for the use of foam is to increase the balance test's sensitivity to detect balance differences. Gerbino *et al.* (2006) used a foam mat placed on top of a Matscan pressure measuring mat to measure COP path length and sway index, while Hrysomallis, (2008) placed a foam mat (40 X 50 X 7cm thick) on a force plate and measured balance as maximum COP excursion in ML direction.

Bernier and Perrin, (1998) used a tilting platform in order to measure a sway index, which is the numerical value of the standard deviation of the distance the subject moved away from the centre of balance. This study measured AP movement.

Holm *et al.* (2004) measured single leg balance on a KAT 2000 (Kinaesthetic ability trainer), which is a moveable platform with a tilt sensor that measures the distance from the central point to the reference position. The platform has a tilt sensor connected to the computer measuring deviation from a reference position. The KAT 2000 provides an assessment of dynamic balance. This can provide an assessment of single leg balance while on a platform. Holm *et al.* (2004) used the KAT (2000) to assess single leg balance. A five step progression was used, from simple to more challenging exercises. The balance program included wobble board exercises very similar to that used in the present study, but there was no specific core stability training. The program was completed three times per week for fifteen minutes in each session for 7 weeks, then one time per week for the rest of the season. Testing was performed at week eight and at one year. Results showed a significant improvement in dynamic balance between tests.

The Biodex stability system is another form of testing used to assess balance (Paterno *et al.* 2004). This testing apparatus is a tilting platform allowing an examiner to objectively measure a subject's balance on an unstable platform. The platform allows for varying levels of balance difficulty from level eight (most stable) to level one (least stable).

While the previous authors used unstable surfaces to assess balance ability, Gerbino *et al.* (2006) suggests that while the stabilometer, seesaw and tilt boards have been used in balance they, offer gross differences in balance compared to normal populations but are not sensitive in distinguishing between healthy populations and particularly elite athletic populations. The use of different surfaces provides a variety of methods of assessing dynamic balance. Devising more difficult balance tests such as placing foam on the force plate increases the difficulty of the test eliciting more subtle change in balance abilities similar to Hrysomallis, (2008).

2.4 Balance training studies in athletes

There have been a significant number of studies assessing balance in the elderly. A small number of studies have assessed balance after joint injuries and then retested after the intervention of a balance program. However, there is no current research investigating single leg dynamic balance capabilities in an elite Australian Rules population throughout an entire season. Table 2.1 outlines balance training outcome studies in able bodied athletes in various sports. These will now be reviewed.

Verhagen *et al*. (2005) evaluated the effect of a balance training programme on COP excursion in single leg stance. Thirty subjects, twenty-two untrained and eight athletes (five male and twenty-five female), participated in the study. Twenty-two subjects were assigned to an intervention group (n=11) or a control group (n=11), while the eight athletes were assigned to a volleyball group. The volleyball and intervention groups completed a 5.5 week single leg balance training program whilst the control group did not complete any training. The intervention program consisted of exercises such as standing on a single leg while throwing balls, and wobble board training. Exercise on the wobble board included one legged stance with the knee flexed. The subject had to maintain balance for 30 seconds and change the stance leg. COP path displacement was calculated through medial-lateral and anterior-posterior movement on the moving force plate with eyes open single leg standing for 15 seconds. The study found that there was no significant change in COP displacement in any groups and between any of the groups ($p<0.05$).

Hoffman and Payne, (1995) investigated the effects of wobble board training on improving the balance capabilities of sixteen male and twelve female high school students who were not athletes. Subjects completed testing on a force plate for 26 seconds standing on their dominant leg only. Testing included maximum COP excursion in AP and ML direction. The control group (n=14) completed no training while the experimental group (n=14) completed balance training sessions that were ten minutes for three times per week for 10 weeks. The Ankle platform system, which is a five stage progression where a rotary force changes the difficulty to balance on the board every 10 seconds for a 40 second trial while standing on the machine was the training program used in the study. The difficulty of the training

Table 2.1 Balance training outcomes studies KAT 2000= Kinaesthetic ability trainer 2000; COP=centre of pressure; AP=anterior posterior; ML= medial lateral; EMG=electromyography`

Author-Study year	Subjects	Balance training program. /Concurrent Sports training.	Outcome Measure	Training frequency and duration	Results COP path displacement
Verhagen *et al.* (2005)	11 intervention group untrained, 11 control group, 8 volleyball group. All university students.	Wobble board single leg stance. / 22 athletes did not play volleyball games while 8 athletes completed 2 x volleyball training sessions and a volleyball game each week.	Force platform. Single leg. (COP path displacement).	2 sessions per week x 5.5 weeks.	COP path displacement decreased. National players>regional players $p<0.001$.
Holm *et al.* (2004)	35 female elite handball players	Wobble board 5 step progression 3 x per week. 1 x per week during season./Concurrent training and playing handball matches.	Balance KAT 2000 (COP 95% ellipse area).	7 weeks 3 x per week. 1 x per week during season.	Area of sway decreased. Test 1-test2 $p=0.01$. Effect maintained for 1 year.
Paterno *et al.* (2004)	41 high school athletes. Age 13-17 years.	Balance training single leg balance (perturbation). Hip pelvis and trunk strengthening	Biodex stability system (COP path displacement).	6 weeks	COP path displacement decreased. Single limb stability $p=0.004$. Ant Post stability $p=0.001$.
Hoffman and Payne, (1995)	14 control, 14 experimental male and female high school students.	Progression 1-5 single leg stance standing on a tilted balance apparatus which changes angle every 10 seconds of a 40 second trial.	Force platform. (ML and AP movement).	10 min (5 trials) 3 x per week for 10 weeks.	ML and AP sway decreased $p<0.05$.
Stanton *et al.* (2004)	22 male athletes Basketball and touch football high school athletes 15.5 years	Swiss ball training. 2 sessions per week./ No mention of concurrent sports training	Core stability. Sahrman level 1-5. EMG of abdominal and back muscles	2 sessions per week x 6 weeks.	Sahrman level increased. Core stability improved $p<0.05$.

tests increased depending on the subject's ability in the progression tests. The results indicated that wobble board training improved single leg balance by 84% in the AP direction ($p<0.05$) and 87% in the ML direction ($p<0.05$) in the experimental group compared to the control group.

Paterno *et al.* (2004) investigated whether balance training improves single-limb balance in young female athletes. The study involved forty-one female school athletes between the ages of 13-17 years without a control group. All subjects were healthy without any injuries. The subjects were tested on a Biodex force platform. This is a tilting platform, which allows for an objective measurement of the subject's ability to maintain dynamic balance on an unstable platform. The subjects stood on the platform for 20 seconds. Subjects did not participate in any other sports training while completing the balance study intervention program. The balance training program incorporated hip/pelvis and trunk strengthening. The initial phase of training over 1-2 weeks involved balancing on two legs on a balance board and back and abdominal strengthening exercises. In weeks 3-4 single leg balancing on the ball and back strengthening on a Swiss ball were incorporated, while in weeks 5-6 single leg balance with perturbation and back hyperextensions were included. The athletes trained three days per week for ninety minutes in each session for 6 weeks. At the end of the program, athletes were again measured using the Biodex force platform measuring anterior posterior and medial-lateral sway. The results of the study indicated a statistically significant ($P<.001$) training effect for improvement between pre and post testing in anterior posterior stability, with an 80% improvement on the right leg and 82% improvement in the left leg.

Holm *et al.* (2004) investigated the effect of neuromuscular training on proprioception, balance, muscle strength, and lower limb function. Participants included thirty five female team handball players with an average age of twenty-three. Nineteen players had previously had ankle instability but only one needed surgery. Nine players had an earlier knee injury. Subjects completed 10-11 training sessions per week for their respective handball teams. No control group was included in the study. A balance training program was introduced including three sessions per week for 5-7 weeks for fifteen minutes each session and once a week and then once a week during the entire season. The training program included wobble board exercises and balance exercises on a mat. Each exercise had a five step progression from easy to difficult. The wobble board program incorporated for example squats on the board, and throwing a ball to each other while standing on the wobble board. Testing was performed at pre training (1week) and then post training (8weeks) and again at twelve months. Testing was performed using a KAT 2000, which is a moveable platform with a tilt sensor connected to a computer that records movement. There was a significant effect (p=0.001) in dynamic balance between test 1 and test 2 (15.8% improvement) with the training effect maintained after one year (6.3% improvement).

Stanton *et al.* (2004) assessed the effect of a 6 week Swiss ball training program on core stability. Twenty-two male adolescent athletes were included in experimental (n=11) and control (n=11) groups from a basketball and touch football secondary school program. Core stability was assessed using the Sahrman five level stability test. This test includes the subject maintaining a natural lordotic curve in supine with an inflatable pad, a Stabiliser pressure biofeedback unit. The subject completes increasing levels of difficulty such as moving either single or both legs while maintaining the same lordotic curve. The Sahrman test consists of five levels of difficulty. To achieve progression to a next level, subject must maintain a lordotic curve change of no more than 10mm Hg. In a crook lying position one leg is lifted up whilst trying to not increase the curvature in the low back. This test provides an assessment of how the trunk musculature can maintain a stable position while moving the lower extremities.

The experimental group completed two Swiss ball training sessions per week for 6 weeks while the control group did not train. Six weeks of core stability training improved the Sahrman test ($p<0.05$). While this test provides an assessment of core stability, it includes sustaining an isometric trunk contraction, while normal core stability of trunk muscle includes primarily concentric and eccentric contraction due to the movement of upper or lower extremities. Therefore the test is not as applicable as a test in an upright position, nonetheless provides an assessment of core stability.

2.5 Core stability training studies in athletes

Core stability training has been a common form of training in both strength and conditioning for athletes and the rehabilitation of low back pain in the rehabilitation setting. However, it is difficult using data from low back pain studies comparing to elite athletes. While research has identified the benefits of core stability training for low back pain (Caraffa *et al.* 1996; Hides *et al*. 1996; O'Sullivan *et al*. 1997; Richardson *et al*. 1999), currently, there is no known studies investigating whether core stability training improves unilateral balance within sports performance.

2.6 Balance training in athletes with injuries

Dynamic balance in Australian Rules football may be a limiting factor in the execution of skills such as kicking and marking. Currently, there is a lack of evidence supporting the assumption that dynamic balance may in fact improve skill execution specifically in Australian Rules football. However, there is evidence supporting dynamic balance training reducing injuries such as ankle and knee injuries. Caraffa *et al.* (1996), found that balance training on wobble boards for example, can significantly reduce the incidence of anterior cruciate ligament injuries in soccer players. Hrysomallis *et al.* (2007) found that low balance ability in 210 elite Australian Rules footballer's measured on a force plate for an entire season increases the risk of ankle sprains. Verhagen *et al.* (2004) found that using wobble boards is effective in preventing ankle sprain recurrences in volleyball players. Other studies have also found that decreased balance ability increases the risk of ankle injuries (Tropp *et al.* 1984, Watson, 1999, McGuine *et al*. 2000).

While also not the focus of the current study, there have been studies, which have included balance training programs for participants with previous injuries or current injuries. Several studies have assessed the effect of training programs on balance capabilities of injured athletes. Gauffin *et al*. (1988) assessed the effect of an 8 week balance training program using a wobble board. The subjects were ten male soccer players with functional instability of the ankle joint. None of the players had completed any balance training before. It is unclear whether the players continued training for soccer while completing the balance intervention program. Training consisted of standing on one leg on wobble boards. The symptomatic leg was trained for ten minute periods five times a week for 8 weeks. Balance was tested using the measurement of COP area of sway while body segmental positions in the frontal plane were identified using a movement recording system. Results showed a significant reduction in COP sway. The area of the COP ellipse decreased by 32%.

Bernier and Perrin, (1998) performed a 6 week balance program in forty-eight non-athletic males and females between 18-32 years who had a history of functional ankle instability. Subjects were assigned randomly to three groups. Group one completed no balance training, group two received a sham treatment and group three completed 6 weeks of balance training. The training program incorporated balance activities on wobble boards. Subjects trained three times per week for ten minutes. Exercises involved eyes open and closed and picking up objects from the ground. Exercises also included using tilt boards in different positions such as either in inversion/eversion, dorsiflexion/plantarflexion or diagonally. Balance was assessed on a force plate and measured using a sway index (standard deviation of the distance of COP sway from the centre of the platform). The training group performed significantly better ($p<.05$) than the sham and no training group.

Tropp and Askling, (1988) investigated the effects of 10 weeks of wobble board training on balance ability in twenty five sub-elite male soccer players who had ankle. The wobble board training program included standing in single limb support. There is no mention whether the subjects were training and/or playing soccer while participating in the study training program. Throughout the first 10 weeks subjects completed ten minutes on each foot five times a week. Then after the 10 week period subjects trained for five minutes three times per week for a further 30 weeks. The testing procedure included single leg standing on a force plate for 60 seconds, measuring the COP area of sway. Balance improved after 10 weeks of balance training ($p<0.001$). Further training was not shown to be beneficial.

2.7 Balance comparison amongst athletes

Athletes who play elite Australian Rules football are a specific population, separate from those who play recreational, high school or university sport. Therefore it is likely that such high level athletes already possess very good balance capabilities. While these athletes have not been compared to those in other sports, the following section reviews balance studies comparing elite homogenous sporting populations in other sports in order to ascertain the extent of these differences.

In addition to a reduction in injuries, balance is also varied among different sports and within different levels of ability at local-elite sport. In elite sportspeople there are also variations in balance ability between sports.

Davlin, (2004) investigated dynamic balance performance in a range of highly skilled athletes. Athletes tested were at a division one, professional, elite or Olympic level. Participants included gymnasts (n=57), soccer (n=58) and swimming (n=70), as well as non sporting control subjects (n=61). Dynamic balance was tested on a stabilometer requiring subjects to maintain an upright posture and make postural readjustments on an unstable platform for 30 sec for seven test trials, which were all the same. The time a subject could maintain balance was measured. Gymnasts performed better in dynamic balance while soccer players were superior to the control group tested. Gymnasts had greater balance than all other groups. Results indicated that 46% of the variability compared to the control group was due to what sport a subject played.

Matsuda *et al.* (2008) investigated the balance ability of athletes during static single leg stance that had played their respective sport for at least six years. Athletes with an average age between 19-21 who participated in the study were from soccer (n=10), swimming (n=10), basketball (n=10) and non-athletes (n=10). All participants completed a single leg balance test on a force plate measuring over 60 seconds. Maximum COP excursion in AP and ML direction, COP velocity and high frequency sway were measured. Results showed no significant difference between groups for single leg static stance on the force plate. However perhaps the test was not sensitive enough to detect differences between groups as static balance standing on one leg is not very challenging. Nonetheless, this study shows that balance ability was not different between these athletes from different sports.

Balance ability can also vary among athletes at varying levels of competition. Paillard *et al.* (2006) compared balance tested on a force platform of national and regional soccer players. Results found that National soccer players had superior static and dynamic balance abilities compared to regional players. Sell *et al.* (2007) also found that golfers off three different handicaps all had different balance ability measured on a force platform. The more superior golfer had superior balance to the other groups.

2.6 Summary

In summary, the mechanism of dynamic balance requires both physiological and biomechanical factors in order to maintain equilibrium. It is the central nervous system and the muscular system, which allow balance to occur. Physiologically, the central nervous system receives messages from the proprioceptors of joints and muscle resulting in movement correction to be made. The muscular system, particularly trunk musculature, provides a structural framework for enabling a stable platform and dynamic balance to be maintained.

Balance has been assessed in various studies in relation to dynamic balance capabilities. Studies have revealed a significant change in balance ability after the intervention of balance training. Research has also shown that elite athletes generally have greater balance ability. Unstable surfaces, such as Swiss ball training have been shown to improve trunk EMG activation of trunk musculature important in maintaining balance control in the upright position. Wobble board training has been shown to improve dynamic balance also.

As mentioned, the studies reviewed have assessed balance in a variety of populations generally over 6-10 weeks. However, there is no current research evaluating single leg dynamic balance ability in an elite Australian Rules team over an entire season. The following training study will investigate the effects of balance training in the Australian Rules footballer over 44 weeks. The next chapter will outline specific aims of the study.

CHAPTER 3 OBJECTIVES OF THE INVESTIGATION

3.1 General aim

1) To investigate the effects of balance training on dynamic balance capabilities of the elite Australian Rules footballer.

3.2 Specific aims

1) To complete a balance and core stability program, over ten weeks during the pre-season then continue during the competitive season for a period of forty-four weeks.

2) To evaluate the balance of subjects before and after the ten week balance program, and again at the completion of the in-season program.

3) To complete a reliability study of the balance testing procedure in order to determine which parameters are reliable to use in the training study.

3.3 Hypotheses (Research)

1) That the intervention of balance training in the pre-season period will elicit significant changes in dynamic balance.

2) Continuing the training program during the subsequent competition season will elicit significant change in dynamic balance capabilities.

CHAPTER 4 METHODS

4.1 Subjects

A group of Australian Football League footballers were recruited to undergo testing. The group included uninjured players from one Australian Rules football club in the Australian Football League (AFL). Informed consent was obtained from each individual player (Appendix 1). The group had no previous experience completing balance training the same as the balance intervention program used. However all of the subjects completed skills, weights and running training as part of the normal overall football training program. Coaching and fitness staff was fully informed of the procedural requirements of the study. A presentation and summarised handout was given to all players and separately to all medical, coaching and conditioning staff.

A control group was not included in the study because it was not possible to find an AFL club not already using a balance program of some description, while following a similar football training program or allowing the research to be conducted. Also a control group was not possible at the study club because the coaches would not allow a control study to occur in highly competitive elite professional team sport such as Australian Rules football. Coaches required all players to participate in the program assuming there would be potential benefits such as improving when kicking and reducing knee ligament injuries.

A reliability study was undertaken in order to establish the reliability of the balance parameters that can be derived from the force platform data. Due to training constraints, the elite Australian Rules footballers were not available to participate in the reliability study. Therefore the reliability study incorporated ten sub-elite male sportsmen who play soccer, Australian Rules or compete in athletics. All were informed of the requirements of the study and signed consent forms to be involved. The tests were conducted 1 week apart using the same procedures and location as the AFL training group. Ethics approval for the study was obtained from Victoria University Research Ethics committee.

4.1.1 Inclusion/Exclusion criteria

It is characteristic of the AFL that a significant number of players train and play with prior injuries. However it was unreasonable to exclude players when the study's aim is to determine balance training efficacy for typical AFL players. However, any player with *current* lower extremity orthopaedic injuries was excluded. It is not possible to specify what injuries were suffered for each player, as that information is not available from the club due to confidentiality. However, knee, ankle ligament and soft tissue injuries were the three predominant medical injuries resulting in exclusion from the research study.

Table 4.1 outlines the inclusion and exclusion criteria used for the training study.

Table 4.1: Inclusion and Exclusion criteria.

Inclusion criteria
1.Senior listed player.
Exclusion criteria
1. Evidence of current orthopaedic lower limb injury. 2. Currently completing a balance training program prior to commencement of the current study. 3. Lower limb injury and/or illness during the study. 4. History of unstable ankle joint limiting unilateral balance capabilities. 5. History of knee injury limiting unilateral balance capabilities.

An attendance record was taken to document training program completion. Consequently the team comprising of forty-two senior players was reduced to twenty-five eligible participants. As the pre-season period commenced, and practice games started, eleven more subjects were excluded due to orthopaedic pathology leaving fourteen subjects who completed all three tests and the full training program with a mean age (SD) of 22 (2.4) years, body mass 88 kg (8) and height 188.9 cm (7) (see Table 4.2).

Table 4.2: Mean (SD) scores for age, height and weight for all training study participant.

	Age (yrs)	Height (cm)	Body mass (kg)
	19	191	81
	19	178	76
	19	184	85
	25	194	93
	20	190	94
	24	183	81
	23	177	82
	21	183	80
	20	201	97
	26	195	98
	22	195	95
	25	189	83
	22	197	100
	23	188	92
Mean (SD)	22 (2.4)	189 (7)	88 (8)

4.2 Balance testing apparatus

The testing procedures were performed in the Biomechanics laboratory, Victoria University, City Flinders campus. The force platform (AMTI Massachusetts 1989, USA, Model number OR6-5 Length-50cm Width 45cm) was mounted in the floor and interfaced to an IBM compatible computer via an analog to digital converter. Vertical and horizontal ground reaction force and moment data were sampled at 50Hz from which centre of pressure was calculated (BEDAS 2 Biomechanics Data-

Acquisition and Analysis Software, AMTI 1989). The sampling rate of 50 Hz was previously used to measure COP by Karlsson *et al*. (2000), Le Clair *et al*. (1996) and Verhagen *et al*. (2005). Table 4.3 lists the centre of pressure equations used to calculate the centre of pressure on the platform.

Table 4.3: Centre of Pressure equation.

$$COP\ X = \frac{(My + dZ.Fx)}{Fz} \qquad COP\ Y = \frac{(Mx + dZ.Fy)}{Fz}$$

Where:	**Description**
COP X	X coordinate of centre of pressure
COP Y	Y coordinate of centre of pressure
X	Anterior-Posterior direction
Y	Medial-Lateral direction
Z	Vertical direction
My	Moment about the Y axis (ML)
Mx	Moment about the X axis (AP)
Fx	Anterior-Posterior force
Fy	Medial-Lateral force
Fz	Vertical force
dZ	distance of the top of the platform to the force sensing origin.

4.3 Balance testing procedure

Balance testing was undertaken at three points during the study (see Table 4.4). Table 4.4 shows the timeline of testing and training throughout the AFL season, and the test schedule (pre-test, post test 1 and post test 2). A total of thirty-four training sessions were conducted in the pre-season and forty-six sessions during the season.

Table 4.4: Timeline of balance testing and training

(Core stability and balance training).

Nov	**Dec**	**Jan**	**Feb**	**April**	**May**	**June**	**July**	**Aug**
Pre-season 20 weeks				In-season 24 weeks				
Pre-test	Post test 1 (10weeks)							Post-test 2 (44weeks)
Balance Training program (wobble board and core stability)								

The subject stood on a wobble board placed on the force platform for the balance tests. The board was made to the following specifications: Radius of wobble board 21.5cm, Height of wobble board 9cm. A rubber ribbed adhesive surface was placed on top of the board in order to prevent slipping in bare feet (Figure 4.1).

Figure 4.1: Wobble board used in all balance testing.

The subjects were given a demonstration of the testing procedure. Subjects were told to aim to decrease movement and hold their balance as best they could. Subjects had their feet shoulder width apart as shown. While balancing single leg, the subject flexed or held the leg straight of the non-supporting leg. Subjects had their eyes open for all tests and were told to look forward at the wall in front of them and remain as motionless as possible for a 20 second test duration (Le Clair and Riach, 1996). The upper limbs were kept close to the body.

All subjects wore a t-shirt, shorts and were barefoot. Subjects completed the test for 20 seconds. Each of the tests comprised standing on the force plate as follows;

1. Standing on Right leg on the wobble board (Figure 4.2).

2. Standing on Left leg on the wobble board (Figure 4.3).

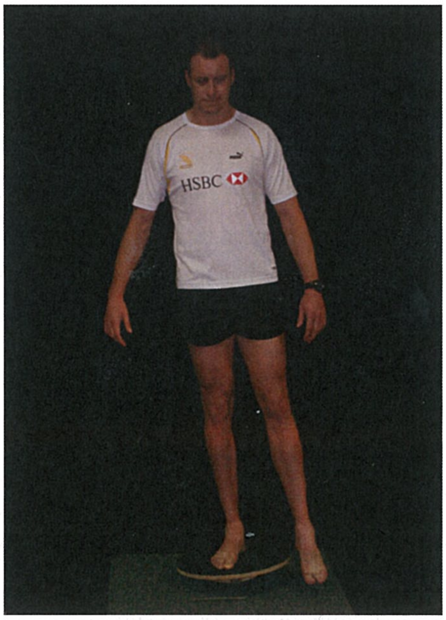


Figure 4.2: Standing on R leg on a wobble board on the force plate

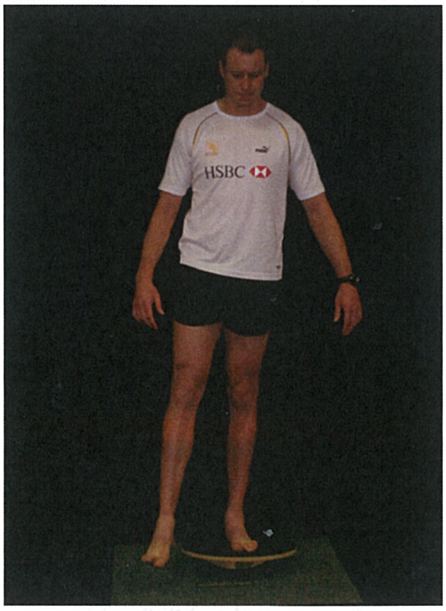


Figure 4.3: Standing on L leg on a wobble board on the force plate

4.4 Data Analysis

Calculated COP data was further processed using the Biomechanics Data-Acquisition and Analysis Software (BEDAS) from Advanced Mechanical Technology Incorporated (Massachusetts, USA). The Computer Automated Stability (CAS) program was used. It computed balance parameters relating to the changes in the centre of pressure in the anterior-posterior (AP) X direction and medial-lateral (ML) Y direction (see Table 4.5).

Table 4.5: COP balance parameters.

AP = anterior-posterior; ML = medio-lateral

Symbol	Description
Xo	COP average AP position
Yo	COP average ML position
Xs	COP AP path standard deviation (SD) from average (Xo)
Ys	COP ML path standard deviation (SD) from average (Yo)
Xm	Mean COP AP displacement from average (Xo)
Ym	Mean COP ML displacement from average (Yo)
Rm	COP path displacement. Distance COP has travelled from average position.
Rs	Standard deviation (SD) of resultant displacement of COP from average position
Cc	Correlation coefficient of AP and ML COP movement.
L	COP path length. Total length of COP distance covered.
Vel	Displacement of COP path divided by time.
Ao	COP path area. The polygonal area of all COP points.
A95	COP 95% confidence ellipse area. The area of the ellipse that includes 95% of normally-distributed COP points
Xmin	COP minimum AP coordinate.
Ymin	COP minimum ML coordinate.
Xmax	COP maximum AP coordinate.
Ymax	COP maximum ML coordinate.

All left and right single leg results were summed. The balance test used in this study included single leg stance because single leg balance is required in the sport of Australian Rules football. A player must kick, mark, sprint, and change direction often off a single leg stance position. While it may be argued that the balance test used in this study is not specific enough to evaluate the dynamic balance of an Australian Rules footballer, at present, balance research is in its initial stages in the sport and there is no gold standard test of single leg balance as it is required in Australian Rules Football. It may also be argued that Australian Rules football is a multifactorial sport requiring many skill elements in varying positions and therefore is hard to compare dynamic balance testing procedures with other research studies from other sports in order to establish a gold standard test for Australian Rules Footballers.

Figure 4.4 represents a subject's typical COP 95% confidence ellipse area result while standing on one leg on the wobble board placed on the force platform.

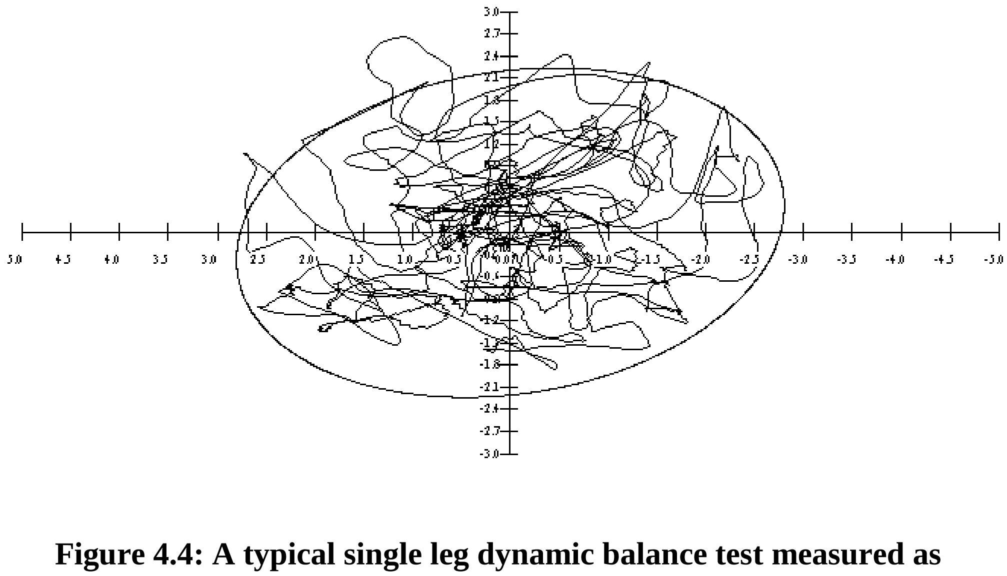


Figure 4.4: A typical single leg dynamic balance test measured as COP 95% confidence ellipse area.

4.5 Training Program

After completing pre-test balance testing, all participants completed a balance training program including core stability and wobble board training, devised by the author based on previous research studies and his knowledge and experience as a strength and conditioning coach in the AFL. The wobble board balance program has exercises similar to studies by Bernier and Perrin (1998); Gauffin *et al.* (1988); Holm *et al.* (2004) and Tropp and Askling (1988). The core stability program includes similar exercises to Paterno *et al.* (2004) and Swiss ball exercises similar to Behm *et al.* (2005).

In addition, to Swiss ball exercises, the core stability program incorporated exercises on other unstable surfaces to increase strength and control of trunk and back muscles. Figure 4.5 shows an example of exercises in the basic, intermediate and advanced stages of the balance training and core stability program.

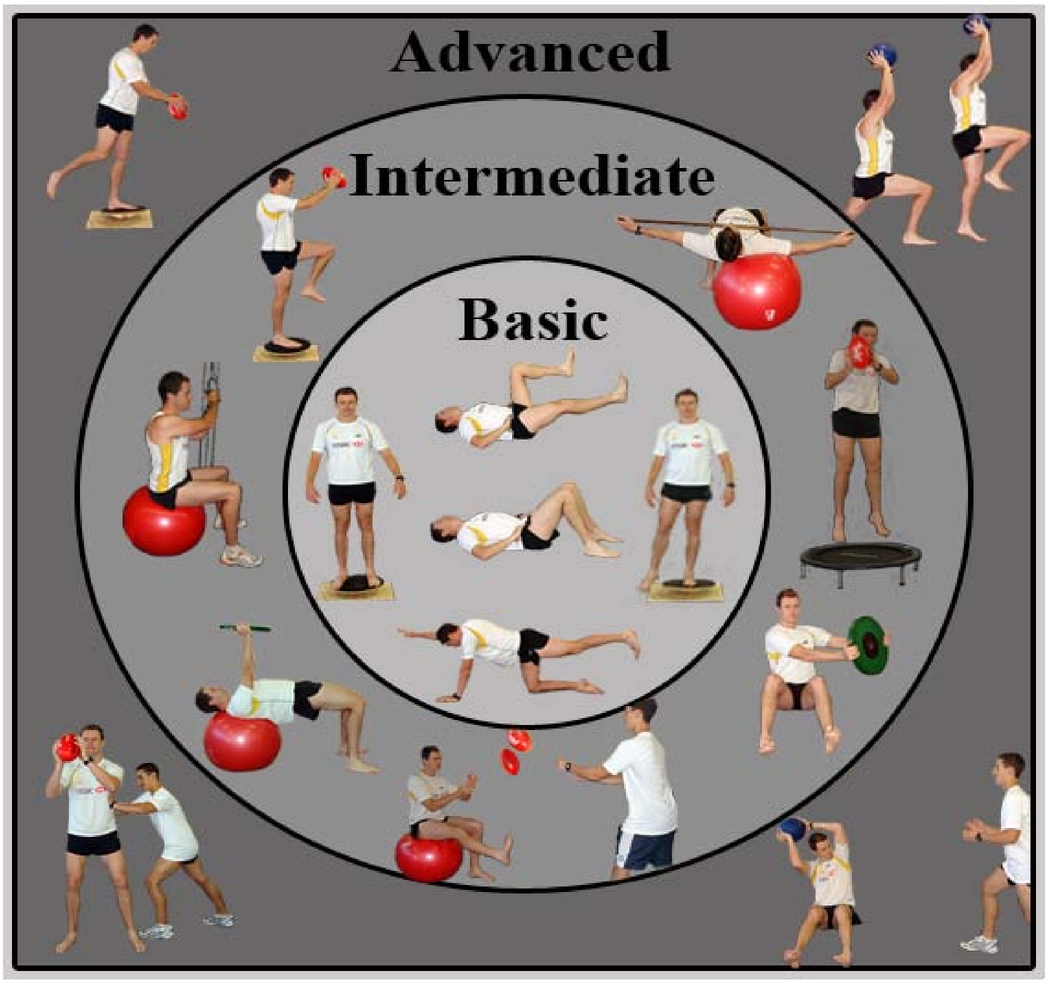


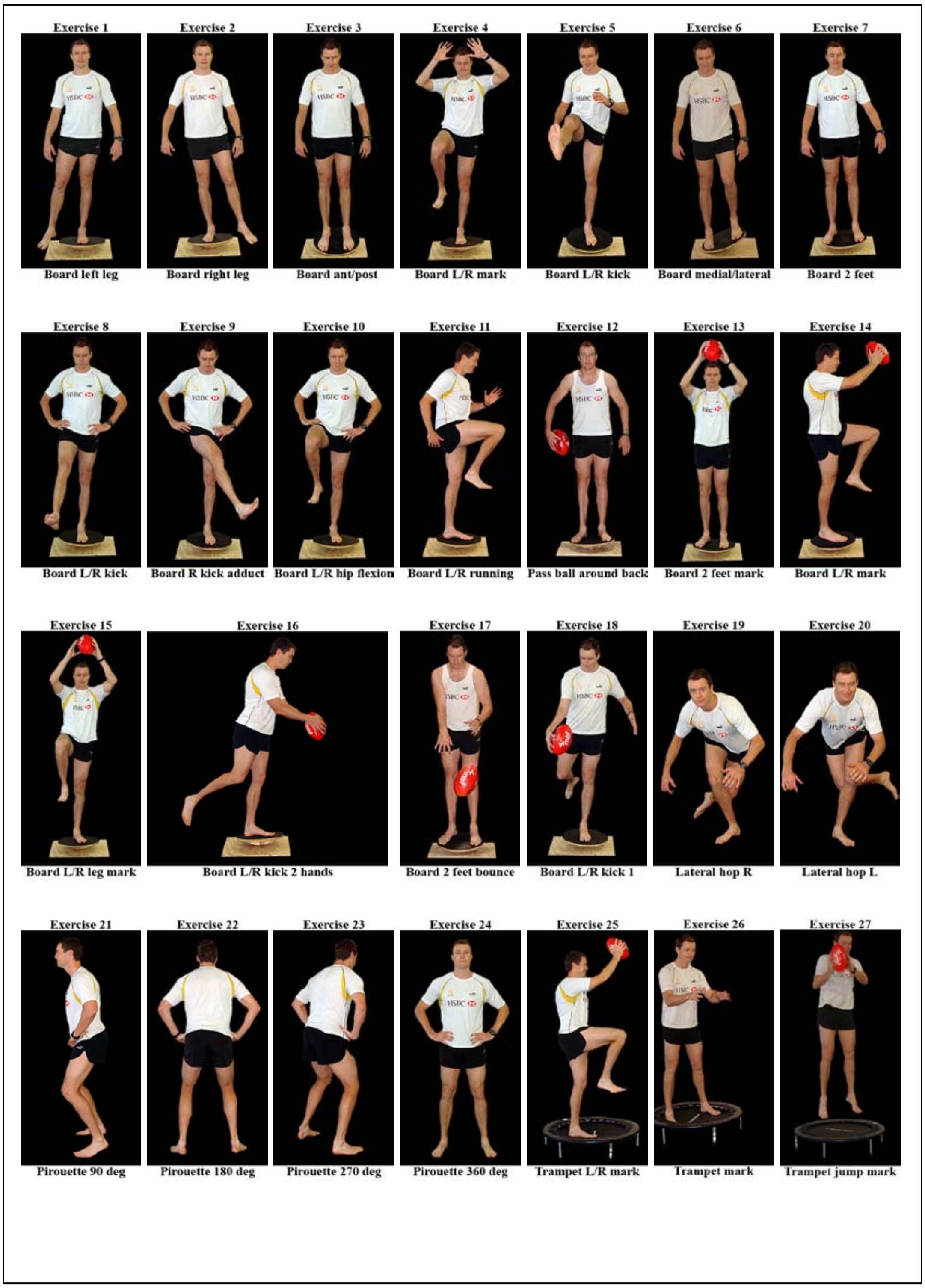
Figure 4.5: The basic, intermediate and advanced stages of the balance training and core stability program.

Stage one, the Basic level, incorporated static activation of stabilising muscle of the trunk and spine. This is designed to simplify the correct learning of activation of deep stabilising muscle with limited peripheral limb movement. The training program included an emphasis on a continuum of trunk exercises from static to dynamic and finally functional core stability exercises in order to improve dynamic unilateral balance. Examples include exercises 1,7,28 and 33 in Figure 4.6. Stage two, the intermediate level, involves more dynamic exercise, which requires a greater balance capability and includes an increased fatigue component.

Intermediate exercises include exercises 14, 27, 34 (a), 40 and 44 in Figure 4.6 (a) and 4.6 (b). Finally stage three, the Advanced level requires stabilising balance in more functionally demanding exercises. These exercises incorporate kicking, marking, bumping and jumping exercises used in playing Australian Rules football. Exercises include number16, 48, 51, 53 and 58 in Figures 4.6a) and 4.6 (b). Appendix 1 describes specifically, the stages of core stability in more detail and an example of a typical core stability session.

Figure 4.6 and Figures 4.7 (a), (b) and (c) shows all of the balance training program, including balance exercises (1-27) and core stability (28-58). Appendix 2 presents an example of both balance training and core stability exercise and their individual exercise sets and repetitions. All exercises range from basic to advanced. As the exercise number increases, the exercise difficulty increases. Figure 4.6 (a) shows all balance exercises used in the training study. Figure 4.7 (a), (b) and (c) includes all core stability exercises used in the study.

The principles on which the program was based are described below. The program was conducted for thirty minutes, two times per week in the preseason (20 weeks) and in the main competition season (24 weeks). It included 15 minutes core stability training and 15 minutes of other balance training such a using wobble boards and balancing on one leg catching footballs.



.**Figure 4.6: Balance exercises included in the training program**

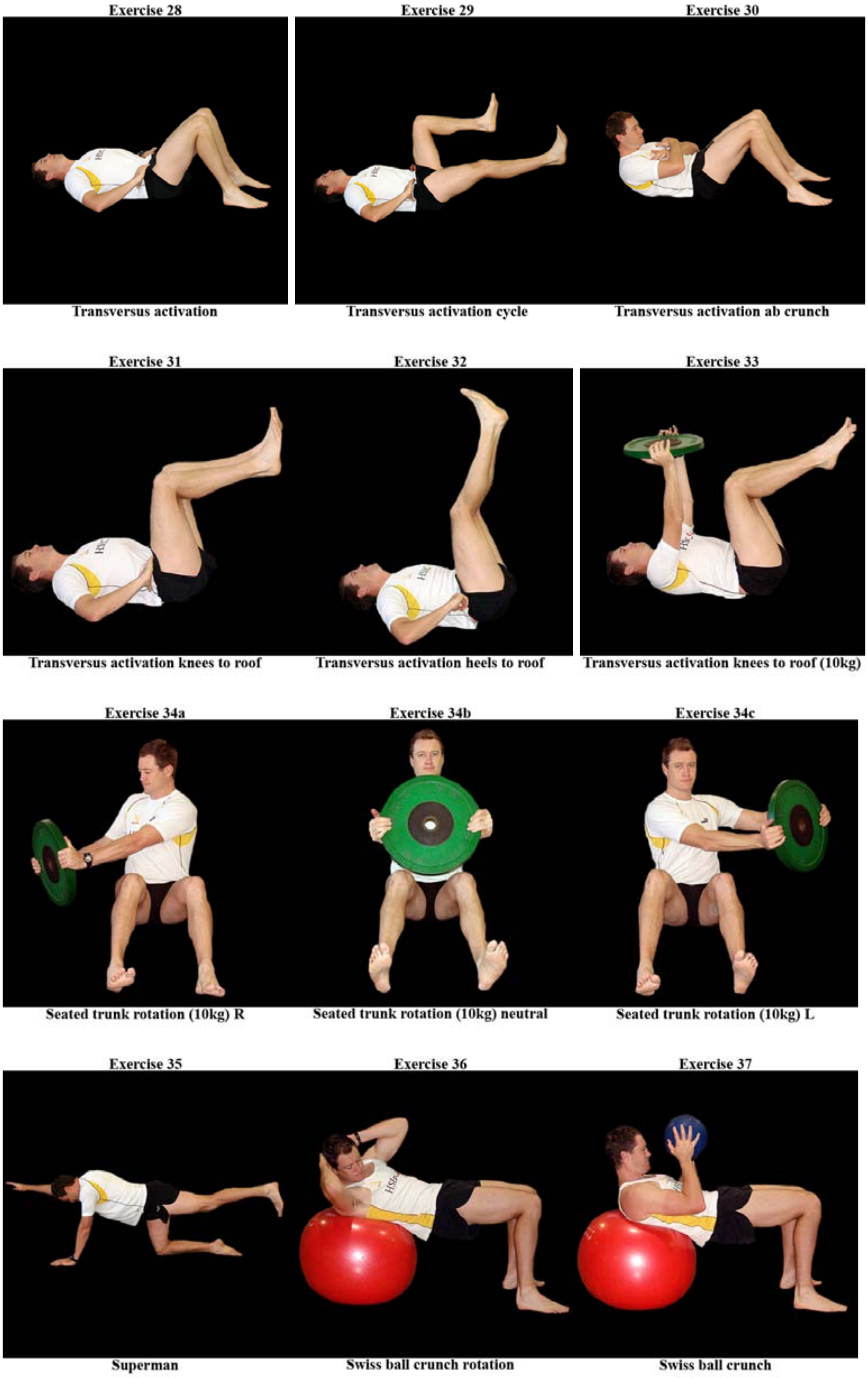
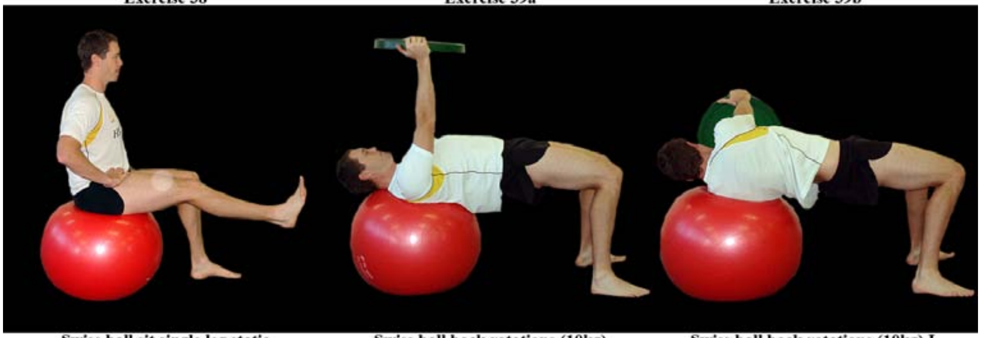


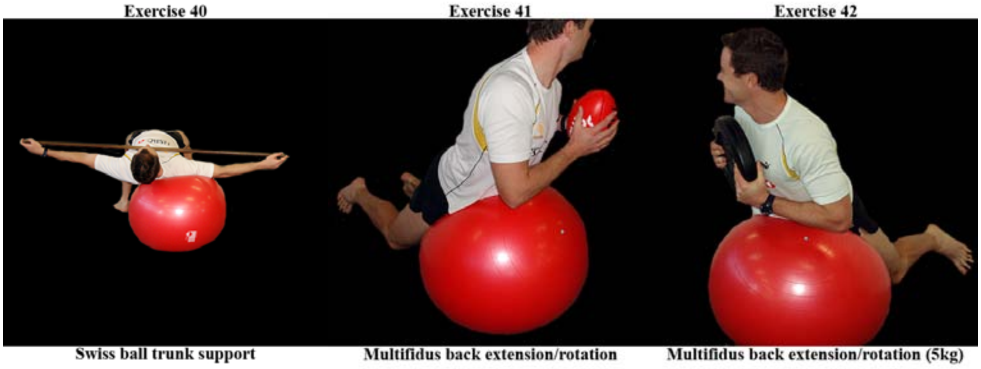
Figure 4.7: (a) Core stability exercises used in the training program

Exercise 38 | Exercise 39a | Exercise 39b



Swiss ball sit single leg static | Swiss ball back rotations (10kg) | Swiss ball back rotations (10kg) L

Exercise 40 | Exercise 41 | Exercise 42



Swiss ball trunk support | Multifidus back extension/rotation | Multifidus back extension/rotation (5kg)

Exercise 43 | Exercise 44 | Exercise 45a

Swiss ball sit single leg mark | Swiss ball sit single leg partner handball | Swiss ball cable woodchop

Exercise 45b | Exercise 46 | Exercise 47

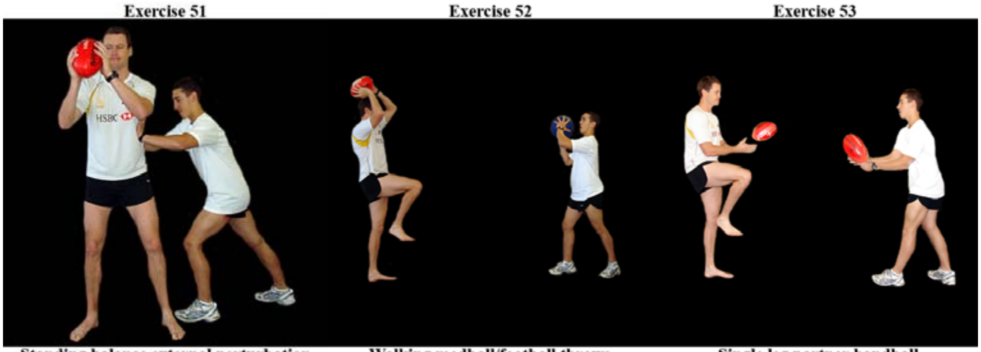
Swiss ball cable woodchop | Swiss ball cable woodchop single leg | Cable woodchop 2 legs

Figure 4.7: (b) Core stability exercises used in the training program (continued).

Exercise 48 | Exercise 49 | Exercise 50

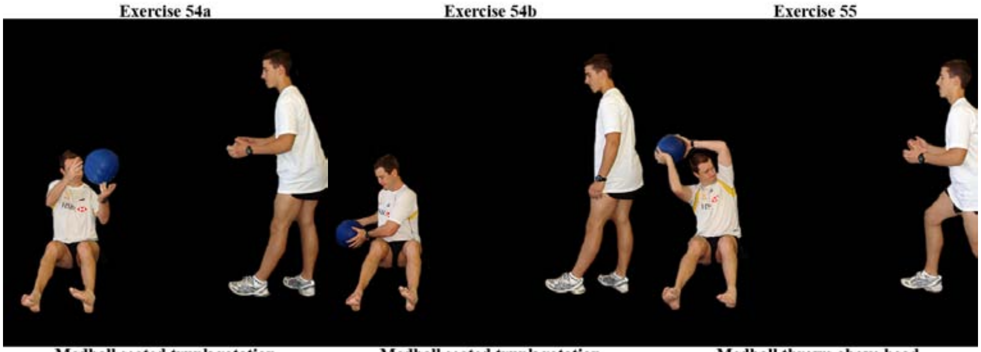
Cable woodchop L/R | Single leg cable woodchop | Standing trunk rotation (10kg)

Exercise 51 | Exercise 52 | Exercise 53



Standing balance external perturbation | Walking medball/football throws | Single leg partner handball

Exercise 54a | Exercise 54b | Exercise 55



Medball seated trunk rotation | Medball seated trunk rotation | Medball throws above head

Exercise 56 | Exercise 57 | Exercise 58

Single leg squat 10kg above head | Walk lunge 5kg medball | Walking slider

Figure 4.7: (c) Core stability exercises used in the training study (continued).

The training program was conducted at the football club training facilities prior to strength training sessions that were part of the team's routine football training program (see section 4.5.4). The author supervised all sessions. Players were trained in groups of ten to allow for adequate supervision and instruction of correct exercise protocol. Figure 4.8 shows players completing the core stability exercise under typical supervision from the candidate. The following sections describe the content of the program in more detail.

4.5.1 Core stability program

The core stability program aimed to strengthen deep stabilising muscles of the trunk and vertebrae. The focus of the program was to achieve a more upright posture with a neutral spine in static and dynamic postural movement patterns. The program aimed to first condition the subject with static strength exercises and included functional core stability exercises relevant to AFL. Figure 4.8 shows participants in a group completing core stability exercises sitting on Swiss balls and having to mark a medicine ball to challenge balance capabilities.

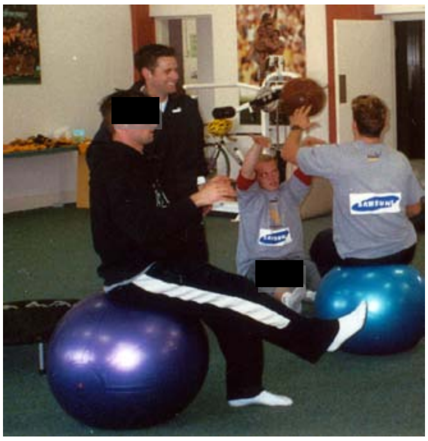


Figure 4.8: Footballers completing the core stability program under supervision.

The core stability program included three stages of development. Figure 4.5 shows the three stages of core stability and balance exercises.

4.5.2 Balance training program

The balance training program includes exercises based around balance development in unilateral dynamic balancing positions. The program included balance and landing activities incorporating wobble boards and change of direction activities similar to Gauffin *et al.* (1988), Holm *et al.* (2004), Paterno *et al.* (2004), Tropp and Askling (1987), Verhagen *et al.* (2005) and Waddington *et al.* (1999). Figure 4.9 shows a footballer standing on one leg on a wobble board completing balance exercises during the training program. The wobble boards used in the training program of the study were previously evaluated as to the effectiveness in encouraging activation of the erector spinae muscle used while balancing particularly during unilateral stance (Burton, 1986). Burton, (1986) found that the dimensions of a wobble board (circular board 350mm diameter set on a ball height of 50mm and of a radius of curvature of 55mm) made of wood, will best activate lumbar extensor activity.

All fourteen subjects in the current study used a wobble board in all training sessions to exact specifications mentioned. The wobble board used in the balance testing was of slightly different dimensions (430mm diameter set on a ball height of 65 mm).

Figure 4.9: A footballer completing wobble board balance training.

Appendix 2 describes a typical balance training session. The program included balance and landing activities incorporating wobble boards and change of direction activities similar to Gauffin *et al.* (1988), Holm *et al.* (2004), Paterno *et al.* (2004), Tropp and Askling (1987), Verhagen *et al.* (2005) and Waddington *et al*. (1999).

4.5.3 Frequency, duration and exercise progressions

During both the pre-season program and in-season, the balance/core training program was included for thirty minutes two times per week.. Figure 4.10 shows a player doing balance training in season. Field testing was conducted weekly in order to assist in keeping players motivated, including both left and right and two legs balancing on a wobble board up to one minute. The program was similar in the preseason and competition season.

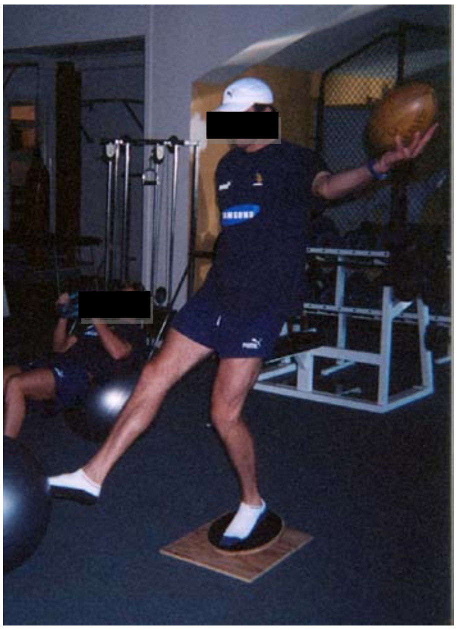


Figure 4.10: A footballer completing the in season balance training program using wobble board.

All exercises range from basic to advanced. As the exercise number increases, the exercise difficulty increases. Players progressed from simple exercises (such as exercise 2 and 3 and 28) to more challenging advanced exercises (such as exercise 18 and 56) as a group so that all participants completed the same training. However, every 3 weeks the program changed allowing physiological adaptation to different, more challenging exercises. The first 1/3 of the program incorporated exercises from figure 4.11 at the basic level. The next 1/3 came from the intermediate section while the final 1/3 of the training program came from the advanced category of exercises. All exercises had specific repititions and sets. Appendix 2 outlines an example of a balance and core stability training session including repititions and sets.

4.5.4 Regular football training program

Players underwent the team's traditional football training program in addition to the balance training intervention. Team training was different through pre season and in-season training programs**.** Table 4.6 includes the pre-season training schedule, including where balance training was included in the program.

Table 4.6: Football pre-season (20 weeks) training schedule.

MON	**Balance training**	Strength training	Kicking skills	Running session
TUE	Yoga	Skills Team	Skills extra	Pool recovery session
WED	**Balance training**	Strength training	Team skills	Speed training
THURS	Skills Individual	REST	Kicking groups	Running session /Skills (Extra)
FRI	Strength training	Pool recovery session	REST	REST
SAT	REST	REST	REST	REST
SUN	REST	REST	REST	REST

During pre-season, general conditioning such as strength sessions and fitness sessions were included more often in the training program. There were six football skills training sessions per week, three strength sessions and three running sessions per week. Skills sessions incorporated 1.5 hour sessions practicing team tactics and football skills. Running sessions included endurance, "lactic" and sprinting sessions of up to one hour duration. Strength training included upper and lower body weight training for 1.5 hours per session. Recovery sessions such as yoga, massage and pool sessions were included.

The balance and core stability training sessions were held prior to the strength training sessions which assisted in the logistical aspects of organising the players into groups. Another benefit of completing the balance and core stability training program before strength sessions was that players were not under neuromuscular fatigue when, attempting to maintain correct postural positions in all balance and core stability exercises while standing unilaterally on unstable surfaces. Table 4.7 outlines an example of a typical team pre-season training schedule.

Table 4.7: An example of the football in-season (24 weeks) training schedule.

MON	**Balance training**	Strength training	Pool	Massage
TUE	Speed training	Kicking groups/ Extra skills	Skills Team	REST
WED	Yoga	Skills Team	**Balance training**	Strength training/ Massage
THURS	REST	REST	REST	REST
FRI	Skills Team	REST	REST	REST
SAT		GAME	DAY	
SUN	Recovery Pool.	Massage	REST	REST

The in-season program included less of an emphasis on fitness and conditioning training and more of an emphasis on team game tactics and skill development. Recovery from football training and playing football matches each week was also a particular emphasis of the in-season training program. The duration of sessions was similar to pre-season. Table 4.7 outlines an example of the team's in-season training schedule.

4.6 Statistical Analysis

All statistical analysis was performed used Statistical Package for the Social Sciences (SPSS) version 14.0.

4.6.1 Reliability study

The reliability study was assessed by an Intraclass Correlation Coefficient (ICC). The reliability results were used to establish which balance parameters were reliable for testing subjects in the training study. ICC's had to be 0.80 or above in order for a parameter to be used for the training study (Cohen, 1988). The ICC used in this study was class **3,1** two way mixed single measure (Shrout and Fleiss, 1979).

4.6.2 Training study

An ANOVA with repeated measures was completed on all reliable variables for the training study. A Post-hoc analysis pair wise comparison was completed to identify the timing of significant differences across the three test periods at an alpha level of $p<.05$.

Effect sizes were established according to Cohen’s standard (Cohen, 1988) as a measure of the magnitude of the treatment effect.

CHAPTER 5 RESULTS

5.1 Reliability study

ICC's were performed on all individual force plate parameters (Table 5.1) for the summed left and right leg scores.

Table 5.1: Intraclass correlation coefficients (ICC) for right and left unilateral stance parameter results combined. AP Anterior Posterior, ML Medial Lateral. * $ICC_{3,1}$ above 0.8

Symbol	Parameter	ICC
Xo	COP average position on plate (AP)	-0.196
Yo	COP average position on plate (ML)	-0.196
Xs	COP AP path SD	0.567
Ys	COP ML path SD	***0.843**
Xm	Mean COP AP displacement	0.629
Ym	Mean COP ML displacement	***0.841**
Rm	COP path displacement	***0.837**
Rs	SD of resultant displacement of COP	0.237
Cc	Correlation coefficient of AP/ML COP	-0.044
L	COP path length	0.716
Vel	COP average speed	0.714
Ao	COP path area	0.749
A95	COP 95% confidence ellipse area	***0.852**
Y min	COP min ML coordinate	0.382
X max	COP max AP coordinate	0.485
Y max	COP max ML coordinate	0.355

The following parameters were deemed reliable (ICC >0.80). These parameters were used in the analysis of the training study.

COP ML path SD

COP path displacement

Mean COP ML displacement

COP 95% confidence ellipse area

5.1.1 Training Study

Statistically significant differences between tests were observed between the testing procedures using an ANOVA (Table 5.2).

Table 5.2: ANOVA with repeated measures and mean (SD) values of each COP parameters included in the test performed.

***p <.05 a) Moderate effect size b) Small effect size**

Parameter	**Pre-test**	**Mean (SD) Post test 1**	**Post test 2**	***df***	**F**	***p***	**Effect Size**
Mean COP ML displacement (cm)	0.881 (-0.150)	0.768 (-0.122)	0.639 (-0.100)	1.458,18.957	21.469	0.01	0.623(a)
COP path displacement (cm)	1.545 (-0.220)	1.342 (-0.147)	1.092 (-0.148)	1.292,16.790	20.387	0.00	0.611(a)
COP path 95% confidence ellipse area (cm2)	27.853 (-7.546)	20.829 (-4.942)	13.913 (-3.388)	1.418,18.437	9.529	0.00	0.479(b)
COP ML path SD (cm)	1.093 (-0.173)	0.944 (-0.141)	0.79 (-0.115)	1.432,18.621	13.444	0.00	0.508(a)

COP 95% confidence ellipse area (*p*=0.00), Mean COP AP displacement (*p*=0.01), COP displacement (*p*=0.00) and COP ML path SD (p =0.00) sway all decreased (p<0.05).

Post hoc analysis revealed that a significant change occurred between pre test, post test 1 and post test 2, and between post test 1 and post test 2 (Table 5.3). Effect sizes were small, moderate and large. According to Cohen (1988) an effect size of 0.20 is small, 0.50 moderate, and >0.80 a large significance of a statistic at p<0.05. Results were of varying effect sizes: medium or large.

Table 5.3: Post hoc analysis of each COP parameters
***p <0.05 a) Large effect size b) Moderate effect size**
c) Small effect size.

Parameters		**Post**	**hoc**		
	Test	***p***	**F**	**df**	**Effect Size**
Mean COP ML displacement (cm)	Pre/ Post 1	0.115	2.882	1	0.115
	Pre/ Post 2	*0.003	14.272	1	0.543[b]
	Post 1/Post 2	*0.002	16.013	1	0.572[b]
COP path displacement (cm)	Pre/ Post 1	*0.036	5.574	1	0.317[c]
	Pre/ Post 2	*0.000	26.185	1	0.686[b]
	Post 1/Post 2	*0.000	27.945	1	0.700[b]
COP path 95% confidence ellipse area (cm2)	Pre/ Post 1	0.005	11.598	1	0.491[c]
	Pre/ Post 2	*0.000	36.908	1	0.755[b]
	Post 1/Post 2	*0.000	32.209	1	0.729[b]
COP ML path SD (cm)	Pre/ Post 1	*0.000	24.985	1	0.676[b]
	Pre/ Post 2	*0.000	50.679	1	0.809[a]
	Post 1/Post 2	*0.002	16.502	1	0.579[b]

Figures 5.1 to 5.4 show the results of the ANOVA with each of the COP variables used in the study. COP path displacement (Figure 5.1) decreased 13.1 % between post test 1 at 10 weeks and 29.3% at post test 2 at 44 weeks compared to the pre test. While post test 1 and post test 2 showed an improvement of 18.6%

Mean COP ML displacement (Figure 5.2) resulted in a 12.8% improvement between pre and post test1 and at post test 2 at 44 weeks a 27.4% improvement compared to the pre test. Comparison between post test 1 and post test 2 showed a 14.6% improvement.

Figure 5.3 shows COP ML path SD revealing a 13.6% improvement between pretest and post test 1, and a 27.7% improvement at post test 2. Post test1 and post test 2 comparison revealed a 16.3% improvement. COP 95% confidence ellipse area (Figure 5.4) saw a 25.2% improvement between pre test and post test 1 at 10 weeks and 49.9% improvement at post test 2 at 44 weeks. Post test1 and post test 2 comparison showed a 33.2% improvement.

The results presented provide evidence towards answering the research hypothesis. The hypothesis of this research was firstly, that the intervention of balance training in the pre-season period would elicit significant changes in dynamic balance. Secondly, that continuing the training program during the subsequent competition season will elicit significant change in dynamic balance capabilities. The next chapter will discuss these results and compare them to other relevant studies.

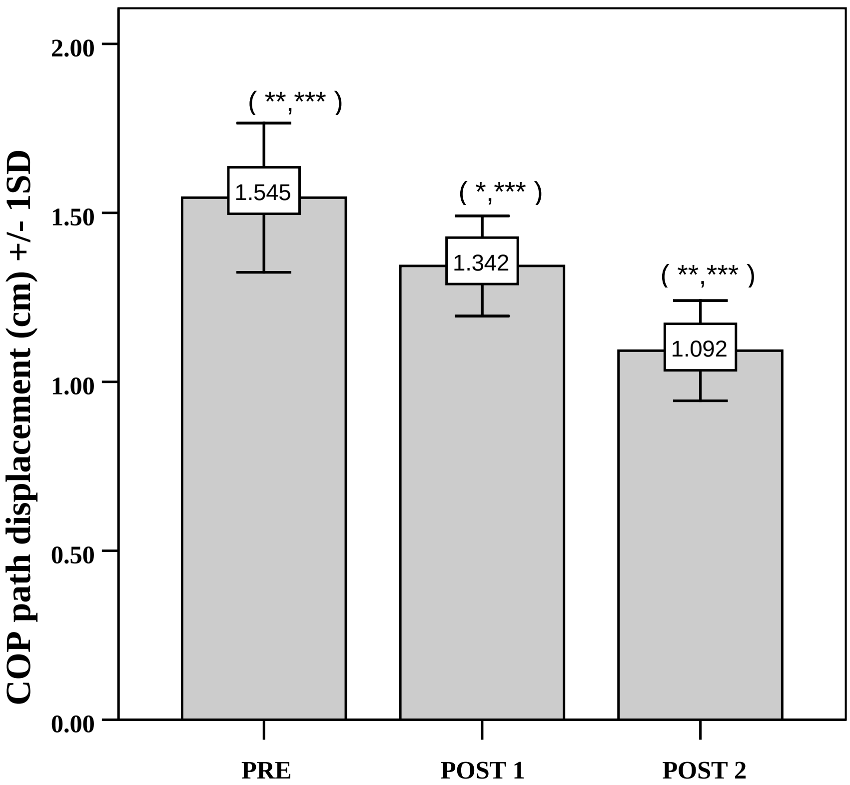


Figure 5.1: **Mean (+/- SD) values for centre of pressure (COP) path displacement (cm) pre-test (PRE), post-test 1 (POST 1) post-test 2 (POST 2).**

Note Statistical significance p <.05 after Post-hoc analysis.

*****,*** Pre- test statistical significant difference between POST 1 and POST 2.***

****,*** Post-test 1 statistical significant difference between PRE and POST 2.***

****,** Post-test 2 statistical significant difference between PRE and POST 1.***

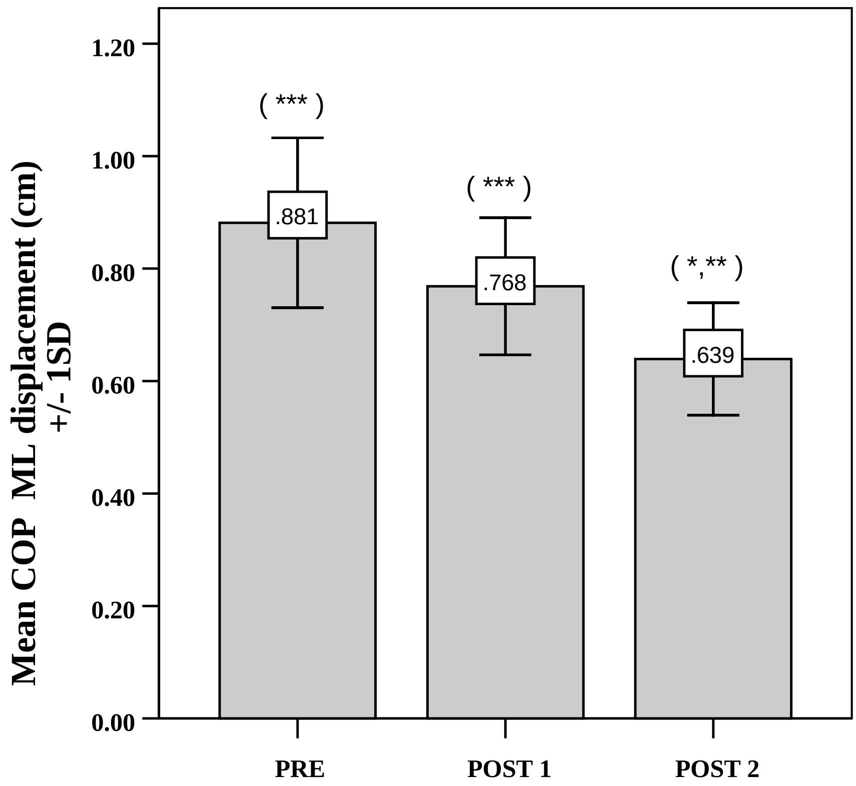


Figure 5.2: **Mean (+/- SD) values for mean COP medial lateral displacement (cm) pre-test (PRE), post-test 1 (POST 1) post-test 2 (POST 2).**

Note Statistical significance p <.05 after Post-hoc analysis.

*****,*** Pre- test statistical significant difference between POST 1 and POST 2.***

****,*** Post-test 1 statistical significant difference between PRE and POST 2.***

****,** Post-test 2 statistical significant difference between PRE and POST 1.***

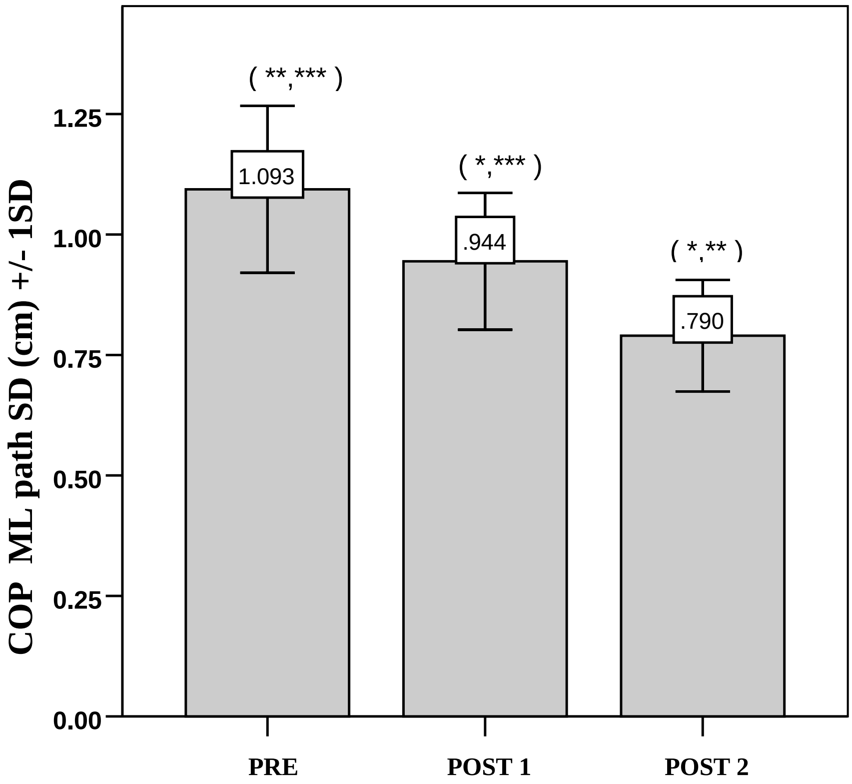


Figure 5.3: **Mean (+/- SD) values for centre of pressure (COP) medial lateral path SD. pre-test (PRE), post-test 1 (POST 1) post-test 2 (POST 2).**

Note Statistical significance p <.05 after Post-hoc analysis.

*****,*** Pre- test statistical significant difference between POST 1 and POST 2.***

****,*** Post-test 1 statistical significant difference between PRE and POST 2.***

****,** Post-test 2 statistical significant difference between PRE and POST 1.***

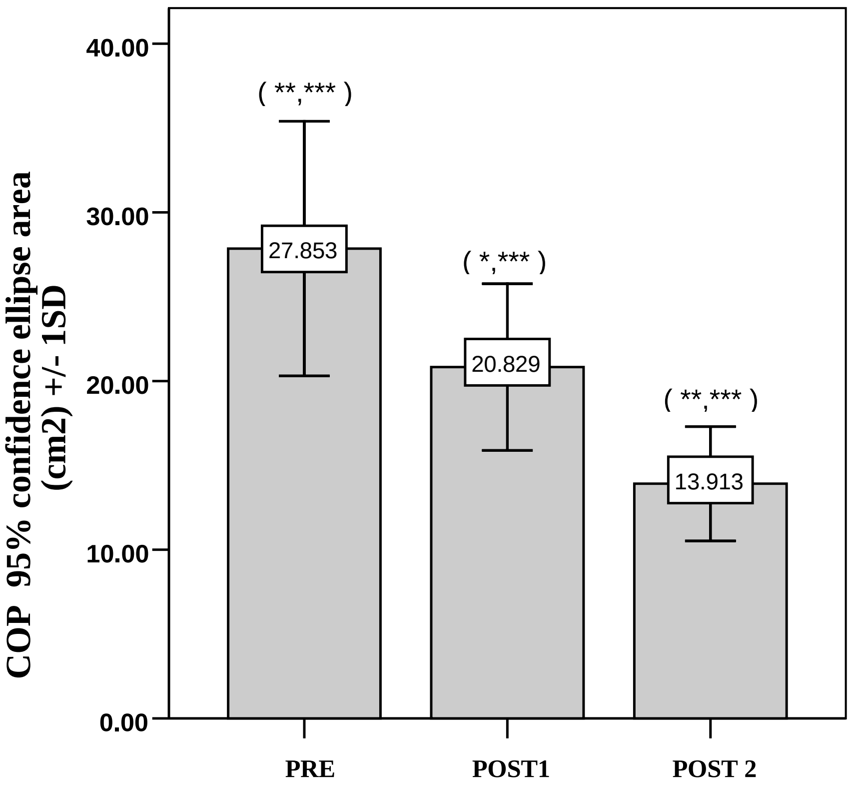


Figure 5.4: **Mean (+/- SD) values for centre of pressure (COP) 95% confidence ellipse area ($_{cm2}$). pre-test (PRE), post-test 1 (POST 1) post-test 2 (POST 2).**

Note Statistical significance p <.05 after Post-hoc analysis.

*****,*** Pre- test statistical significant difference between POST 1 and POST 2.***

****,*** Post-test 1 statistical significant difference between PRE and POST 2.***

****,** Post-test 2 statistical significant difference between PRE and POST 1.***

CHAPTER 6 DISCUSSION

6.1 Reliability

If the reliability of methods is unknown, it is important to conduct a reliability study prior to a training study to ascertain whether the testing procedure is in fact reliable enough to be used in the training study. In the current reliability study, ten subjects from sub-elite team sport were tested twice one week apart. Reliability testing of the single leg dynamic tests on a wobble board placed on the force plate revealed that only some parameters had acceptable reliability (ICC>0.8). The following variables were found to be reliable and were therefore used to assess the training study: COP 95% confidence ellipse area (ICC=0.852), Mean COP ML displacement (ICC=0.841), COP ML path SD (ICC=0.843) and COP path displacement (ICC=0.841).

Several previous balance studies have not included reliability studies prior to commencing the main training program. Hoffman and Payne, (1995), Holm *et al.* (2004) and Verhagen *et al.* (2005) did not complete reliability studies prior to commencing the main training program, nor did they provide any other evidence of reliability from previous studies. It would have been better to first establish reliability of the tests to increase the chances that these tests would detect statistically significant results. Without a reliability study it can only be assumed that the testing procedure will elicit a statistically valid result.

It may be postulated that studies, which have found no statistical change in balance with training, may be because of unreliable methods. Verhagen *et al.* (2005) found no statistical change in balance after a 5.5 week training program but did not complete reliability testing. Therefore, perhaps a change in balance due to the training program could not be detected because the measurement used was not reliable.

Hrysomallis, (2008) investigated reliability of a balance testing protocol in Australian Rules footballers on two consecutive days on a force plate. Testing included single leg stance for 20 seconds, while standing on a foam mat placed on top of a force plate. The ICC was 0.81 for Max COP excursion in ML direction.

Paterno *et al.* (2004) completed a reliability study on a Biodex stability system force platform. However, only five healthy high school athletes were included. ICC's were 0.77 for AP stability, and 0.81 for ML stability.

In comparison to the current study, Hrysomallis, (2008) used elite Australian Rules footballers while Paterno *et al.* (2004) included high school athletes and the current study used elite athletes. However, sub-elite athletes were used in the reliability study, as elite athletes could not be accessed for that. Hrysomallis, (2008) tested COP measurements in subjects standing on top of a foam mat placed on top of the force plate; similarly the current study measured COP with subjects standing single leg on a wobble board placed on the force plate. All three studies found ICC's between 0.801 and 0.841.

6.2 Balance training

At present, there has been no published research assessing whether dynamic single leg balance ability may be improved in an elite Australian Rules football team with a balance and core stability program over the duration of an entire AFL season. Therefore, the current research was established to investigate whether in fact balance and core stability training would improve single leg balance while standing on a wobble board placed on the force plate. It was hypothesized that balance ability would improve after completing a balance training program. Completion of a structured balance program resulted in a significant change in single leg balance ability on the force platform. The improvement was developed over a 44 week period, with significant change after both 10 and 44 weeks after initial pre testing.

Mean COP ML displacement, COP path displacement, and COP ML path SD all showed a reduction in COP sway ranging between 13.0% -13.5% after 10 weeks of training, while COP 95% confidence ellipse area reduced by approximately 25%. After 44 weeks of balance training Mean COP ML displacement, COP path displacement, and COP ML path SD also showed a similar reduction in COP sway, while 95% confidence ellipse area reduced further, by approximately 50% between pre testing and 44 weeks. Between post test 1 at 10 weeks and post test 2 at 44 weeks, the three parameters mentioned showed 14.5%-15.0% reduction in COP sway, while COP 95% confidence ellipse area reduced by approximately 25%. Figure 6-1 provides a graphical summary of the results for post test 1 and post test 2 including Mean COP ML displacement, COP ML path SD, COP sway and COP 95% confidence ellipse area

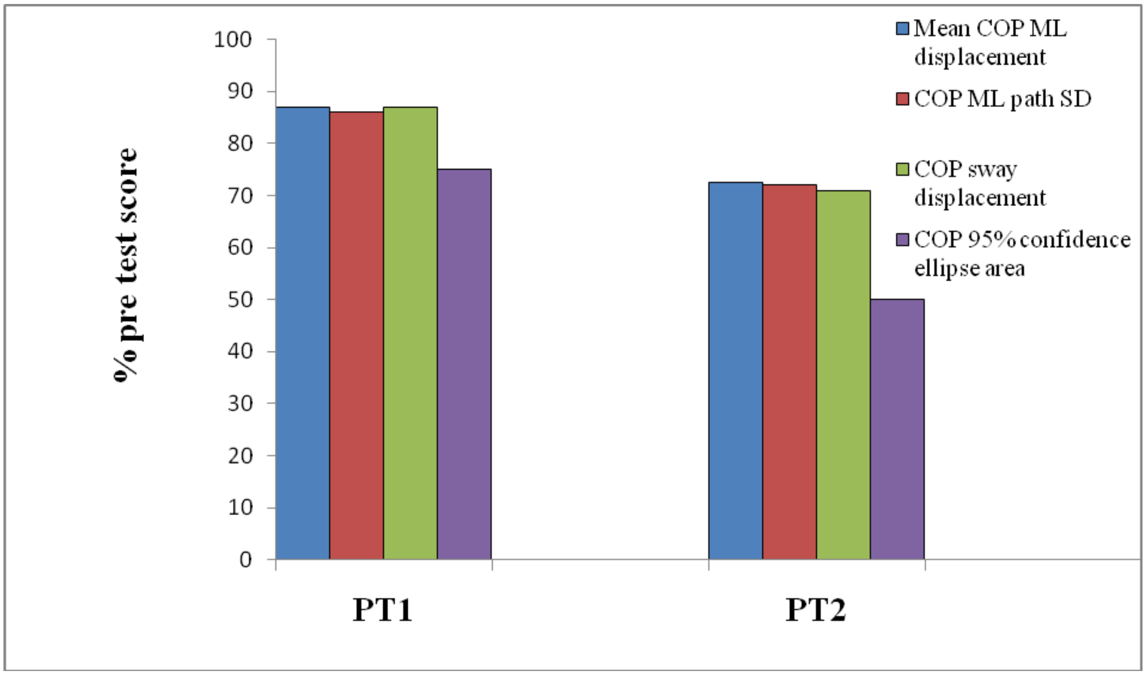


Figure 6.1: COP parameters at post test 1 (PT1), post test 2 (PT2), expressed as % of pre-test score.

Several studies have been completed to the current study with a similar balance training program. Studies have revealed significant balance improvements while completing balance training over a 6-8 week period (Bernier *et al.* 1998; Hoffman and Payne, 1995; Holm *et al.* 2004; Paterno *et al.* 2004). However, there are no other studies that have assessed the combination of balance and core stability training in athletes using a force platform.

Holm *et al.* (2004) assessed dynamic balance in elite handball players by the subject standing on two legs on a KAT 2000 movable platform with a tilt sensor. Balance was measured on the sensor using a balance index, which measures the subject's distance of movement from a central point to the reference position. Subjects completed a balance training program in addition to ten hours per week of regular handball training.

Holm *et al.* (2004), and the current study included a similar wobble board training program, but Holm *et al.* (2004) did not include a trunk strengthening program. In addition, both Holm *et al.* (2004) and the current study, completed testing three times throughout a one year period. This study revealed similar methodology and results to the current study including using elite athletes from team sports tested over similar testing periods after 8 weeks and twelve months.

Holm *et al.* (2004) found a significant dynamic balance improvement at 8 weeks measured by the KAT 2000, while the author found a significant improvement in single leg balance at 10 weeks. At one year Holm *et al.* (2004) found a 21% improvement in dynamic balance while the current study at one year found a 50% improvement in dynamic balance. Holm *et al*. (2004) used a KAT 2000 to measure a balance index, while the author used a force plate with a wobble board.

Paterno *et al.* (2004) assessed whether trunk and balance training would improve single leg balance measured on a force platform in healthy female athletes. The training program included similar methodology to the authors study, The period between pre testing and post testing was 6 weeks, while in the current study it was 10 weeks between pre-test and post test 1**.** Paterno *et al*., (2004) showed 18%-20% improvement in balance over the 6 weeks, similar to the current studies findings of 15%-25% improvement in balance over 10 weeks. This study provides some further evidence that both balance and core stability training can improve single leg balance. Results revealed similar findings to the current study, that after completing similar balance and core stability training to the current study, over 6 weeks, single limb balance improves. This further suggests that combining both forms of balance training can improve single leg balance in able bodied athletes.

Verhagen *et al.* (2005) investigated the effects of balance training on COP excursion in ML direction in one leg stance over 5.5 weeks and found no change in dynamic balance ability. Subjects were thirty healthy non-athlete university students who were divided into a control group, intervention group and an organized volleyball training group. The training intervention program incorporated many exercises using wobble boards and other balance exercises very similar to the current study. COP excursion in ML directions was assessed. Results showed no significant change in the test results for any group, and there was no difference between the groups.

Verhagen *et al.* (2005) suggested that their healthy subjects may have high balance baseline scores as they all participated in university sport, thereby perhaps limiting their potential for improvement. Also the sample size for each group was small reducing statistical power. Perhaps 5.5 weeks was not long enough to allow for a significant balance change. Hoffman and Payne (1995) completed 10 weeks of training, Holm *et al*. (2004) completed one full year of training while the current study completed a training program for 44 weeks. The training program consisted of two balance training sessions per week up to 15 minutes each. The author's study included 30 minute sessions. Perhaps 15 minutes is not enough for training balance over two sessions per week in order to elicit balance change.

Hoffman and Payne, (1995) assessed the effects of wobble board training on healthy subjects, however they were non-athletes. The balance training program included exercises on wobble boards similar to the current study, for 10 weeks of training. Training sessions were 10 minutes in duration; the current study used 30 min. Both studies used force plates to measure balance and found that balance ability in the COP excursion in ML directions improved over 10 weeks. ML sway decreased by 16%.

The studies reviewed reveal that balance training incorporating wobble board training, trunk strengthening or a combination of both can improve dynamic balance. While the current study and other studies reviewed may have measured balance differently they all included balance training programs. Holm *et al.* (2004), and the current study included a similar wobble board training program, but Holm *et al.* (2004) did not include a core stability program.

However, Hoffman and Payne *et al.* (1995) and Verhagen *et al.* (2005) did not include athletes, in their subjects and Paterno *et al.* (2004) used different testing measures and only trained for 5.5 weeks.

6.3 Force plate balance testing using unstable surfaces

An important aspect of the current study was the use of an unstable surface for balance assessment. Davlin, (2004), Gerbino *et al.* (2006), and Guillou *et al*. (2007) all found that those with increased balance demands in their sport, and who play at a higher level, show decreased COP sway in tests, as opposed to a control group or a sport with less balance demands. Therefore, Gerbino *et al.* (2006) suggests that elite athletes need tests, which are more sensitive to balance change. Various studies have used foam mats, tilt boards, seesaw apparatus such as tilting platforms and movable platforms to provide a more difficult test sensitive to changes in balance in healthy elite populations.

In the current study, the author decided to test dynamic balance on the force plate by placing a wobble board on the plate, increasing difficulty to balance while standing on one leg. Elite Australian Rules footballers are well conditioned athletes therefore the test was designed to evaluate balance in a healthy population who should already have excellent balance capabilities in order to challenge dynamic single leg balance capabilities.

Paillard *et al.* (2006) used a seesaw device on top of the force plate to generate further instability, Bernier and Perrin, (1998) used a tilting platform to evaluate AP movement while Paterno *et al.* (2004) measured single limb stability on a Biodex stability system which is a moving force plate which measures AP and ML movement for varying levels of difficulty between 1 (least stable) and 8 (most stable). Hrysomallis (2008) assessed balance in elite Australian Rules footballers using foam placed on top of a force plate while Gerbino *et al.* (2006) used foam on top of a Matscan pressure mat.

Based on the fact that the current testing procedure proved reliable and detected significant changes over time with training, the wobble board test should be replicated in future studies in elite athlete populations.

The balance test used in this study included single leg stance because single leg balance is required in the sport of Australian Rules football. A player must kick, mark, sprint, and change direction often off a single leg stance position.

While it may be argued that the balance test used in this study is not specific enough to evaluate the dynamic balance of an Australian Rules footballer, at present, balance research is in its initial stages in the sport and there is no gold standard test of single leg balance as it is required in Australian Rules Football. It may also be argued that Australian Rules football is a multifactorial sport requiring many skill elements in varying positions and therefore is hard to compare dynamic balance testing procedures with other research studies from other sports in order to establish a gold standard test for Australian Rules Footballers.

6.4 The training program

As previously mentioned, to clarify the term ‘balance training’ in the thesis title, this includes balance training such as on wobble boards, and core stability training such as using Swiss balls. The wobble board and core stability training program used throughout the present study was similar to other studies (Bernier and Perrin 1998; Gauffin *et al.* 1988; Hoffman and Payne 1995; Holm *et al.* 2004; Paterno *et al.* 2004; Stanton *et al.* 2004; Verhagen *et al.* 2005). Table 2.1 outlines the balance training studies. However the current study included many more functional wobble board and core stability exercises relative to single leg balance requirements in Australian Rules football.

Various programs training balance have provided some interesting insights and comparisons to the current study. The training program in the current study included a comprehensive core stability and balance program. Firstly, Verhagen *et al.* (2005) used similar single leg balance training in their study of the effect of a balance training programme on centre of pressure excursion in one leg stance measured on a force plate. Paterno *et al.* (2004) included similar balance activities and balance board activities in their study of whether neuromuscular training improves single limb stability in young female athletes. Balance was measure using the Biodex stability system. Stanton *et al.* (2004) included core stability training through using Swiss ball training similar to the current study in their study of the effect of short term Swiss ball training on core stability and running economy. Core stability was measured using the Sahrman test. Holm *et al.* (2004) also completed similar core stability and wobble board training as part of their intervention program measuring balance on the KAT 2000. While using different methods of evaluating balance, all of these studies found significant improvements in balance ability while Stanton *et al.* (2004) found an improvement in core stability measured using the Sahrmann 5 level stability test.

The core stability training program used in the study presented has included aspects of other core stability programs previously supported in research. The current core stability program incorporated inner abdominal muscle training with the intention to improve functional single leg dynamic balance. The training program was similar to Vezina and Hubey-Kozey (2000). Their study researched muscle activation patterns of the abdominal muscles. Stable exercise advance to more dynamic requiring a greater functional trunk conditioning using unstable surfaces such as Swiss balls and wobble boards with the aim of increased trunk muscle activation, challenging balance ability. Research has revealed that a Swiss ball as used in the current study increases core musculature activity as opposed to stable exercises (Anderson *et al.* 2004, Behm *et al.* 2005 and Vera-Garcia *et al.* 2000). The current study included balance training comprising of standing single-leg on wobble boards *and* completing resistance exercise on a single leg in order to alter the base of support and increase the core stability / spinal stabilisation component of unilateral balance.

This form of altering the base of support has been used within core stability and single leg balance programs has been used in other studies to increase activation of core musculature important in the maintenance of balance (Anderson and Behm, 2004; Behm *et al*. 2003; McCurdy and Conner, 2003; Vera-Garcia *et al.* 2007; Willardson, 2007). While, Stephenson and Swank, (2004) suggest core strength should include exercise in an unstable environment as well as dynamic exercises. The current program in the advanced stage, included exercises on unstable surfaces while using weights, medicine balls and footballs to further challenge both core and balance mechanisms.

Consequently, it is difficult to say which core stability program is the most effective to improve balance. Core stability training is still in its infancy with currently more formal research focus in clinical applications. Future studies needs to compare methods of core stability training to see what method most improves dynamic balance the most. Also, while a standard test for core stability needs to be established.

Since the current study did not include a control group, it is difficult to conclude definitively that the training program alone improved balance. However, Hrysomallis (2008) completed a study with twenty-eight professional Australian Rules players who did not complete a balance training program but rather their normal football training program. This compromised football training, weight training and running sessions were similar to the football training program in the current study. The purpose of the study was to investigate whether there was a difference in balance ability between week 1 and week 11 during the 22 week season of an elite Australian Rules footballer. Subjects were tested on a force plate with foam placed on top, for medial-lateral sway (mm) in both limbs. Results of the study revealed no significant change in medial-lateral sway on the force plate. Hrysomallis (2008) suggests that normal football training programs are insufficient in duration, specificity or frequency to alter balance abilities. While the current study did not include a control group, Hrysomallis (2008), using similar methodology to the current research provides an indication of what results might be expected from a control group. Hrysomallis (2008) study reveals that between the testing periods, without the intervention of a balance program for Australian Rules football, single leg balance measured as sway did not improve. Also the current study has revealed a statistical change in balance ability after the intervention of a balance training further suggesting that balance training may be the reason for balance improvement.

Results of the current study suggested a significant change in balance between pre and post testing at week 10 and in week 44 at the end of the training program, with the addition of balance training. The significant statistical improvement occurred between 0-10 weeks, 0-40 weeks and 10-40 weeks. It is interesting to see a 14.5%-15.0% change in mean COP ML displacement, COP path displacement and COP ML path SD while a 25% improvement in 95% confidence ellipse between 10 weeks and 44 weeks. This suggests that balance improvement is initially improved after 10 weeks of training, but can be further developed after 44 weeks. After a full 44 weeks of balance training an improvement of approximately 25 % for COP ML displacement, COP path displacement and COP ML path SD and approximately 50% for the 95% confidence ellipse reveals that a continuing balance program may be needed to maintain improved balance ability already developed over 10 weeks.

6.5 Limitations

There are other factors which may have contributed to the improvement in balance ability in the current study. Between the balance tests the participants trained on the wobble boards each session for 44 weeks. Perhaps the improvement was based on a learning effect of training on wobble boards and then being tested on wobble boards, even though training and testing wobble boards were of differing dimensions, and not the other aspects of the training program.

As previously noted, a limitation of this study was that a control group was not included. This was because the coaching staff at the club wanted all players to complete the balance program. Also other elite Australian Rules football clubs have various training programs, which include aspects of the program that the candidate used in the training study that would have made them unsuitable controls. Therefore, it is not possible to say conclusively that the balance improvements observed were due to balance training alone. The balance requirements of normal football training and competition may have also contributed. However the results of Hrysomallis, (2008) with a similar Australian Rules football team suggests that this is perhaps unlikely. Hrysomallis, (2008) study highlights that football training on its own without the intervention of balance training, isn’t sufficient to change balance capabilities in the elite Australian Rules footballer. This further supports the current studies findings, that the intervention of balance training significantly improved balance capabilities. While it has been acknowledged that it may not be balance training alone that is improving single leg balance, the current study found that after both 10 and 44 weeks balance ability significantly improved.

The current study included only fourteen subjects, for various reasons. Firstly, forty-two players were included in the initial training study group, but were excluded due to various lower limb injuries occurring throughout the competition season. Consequently, the number of subjects used in the study was reduced to fourteen. Secondly, because all subjects were from an elite Australian Rules football team, coaches wanted all players to complete all training sessions including balance sessions. Also it was difficult to get another group at another elite Australian Rules team due to teams not wanting training information advertised, and because staffing the training intervention group would have been too difficult. However despite the low number of subjects, a significant change was still found.

A limitation of the current study is the inability to determine what aspect of the training was most responsible for the training effect. In future studies it would be interesting to have 4 groups, with group 1 completing wobble board proprioceptive training only, group 2 completing core stability training only, group 3 completing both wobble board and core stability, and a control group not completing any balance training at all. Given the difficulty in maintaining a reasonable number of uninjured players for the current study, this may be impractical. However, such a study would show if one method is more worthwhile in a "time poor" overall football training program. Elite Australian rules clubs have limited time to place a balance program in addition to team skills, individual skills, strength sessions, tackling session, kicking sessions, running sessions, physiotherapy and medical assessments, team meetings and individual video analysis sessions.

6.6 Future research

In addition to addressing the limitations of the current study, future studies should assess whether the balance training program presented improves actual Australian Rules football skills.

Also, while it was not the intention of this study to assess whether balance training reduces injuries such as ankle ligament and knee anterior cruciate ligament injuries, this is an important topic for future research.

CHAPTER 7 CONCLUSIONS

In summary the research hypothesis included two aspects: firstly, that the intervention of balance and core stability training incorporating in the pre-season period would elicit significant changes in dynamic balance; secondly that continuing the training program during the subsequent competitive season would also elicit significant change in dynamic balance capabilities. The present study included a balance training program combining balance exercises such as wobble board, jumping and landing, and core stability training. The results indicated that balance training significantly improves dynamic balance as assessed on a wobble board placed on a force platform at the end of preseason and in-season competitive period. This research highlights the importance of completing balance training over longer periods than 8-10 weeks and that balance of an elite Australian Rules footballer can continually improve over a longer competition period.

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APPENDIX 1

Victoria University

Consent Form for Subjects Involved in Research

CERTIFICATION BY SUBJECT

L,
of

certify that I am at least 18 years old and that I am voluntarily giving my consent to participate in the experiment entitled:

The effects of balance training on dynamic balance capabilities in the elite Australian Rules footballer.

being conducted at Victoria University of Technology by:
Adam Larcom, Tim Wrigley and Prof. Rezaul Begg.

I certify that the objectives of the experiment, together with any risks to me associated with the procedures listed below to be carried out in the experiment, have been fully explained to me by:

Adam Larcom

and that I freely consent to participation as described below:

- **Balance testing, before and after 10 and 44 weeks of normal club balance training. Testing involves standing on a wobble board with either both feet or one foot for less than a minute, 3 times.**

I certify that I have had the procedures explained to me, and had the opportunity to have any questions answered. I understand that I can withdraw from the testing at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the data collected will be kept confidential amongst the research staff. Club medical or coaching staff may also wish to review the data.

Signed: .... }

Witness other than the experimenter: } Date: ....

....}

Any queries about your participation in this project may be directed to the researcher (Name: Adam **Larcom** ph.). If you have any queries or complaints about the way you have been treated, you may contact the Secretary, University Human Research Ethics Committee, Victoria University of Technology, PO Box 14428 MCMC, Melbourne, 8001 (telephone no:).

APPENDIX 2

<u>Core stability program</u>

<u>Stages of core stability (activation of deep stabilising muscle).</u>

1. Basic localized stage. At this stage deep stabilizing muscles of the pelvis and vertebrae are targeted by focusing attention on them.
2. Intermediate stage. The purpose of this stage is to develop the ability to activate and use stabilising muscles in a variety of movements.
3. Advanced stage. Exercises now become more functional to the sport of Australian Rules football while relying further on the use of stabilising muscle in movements challenging unilateral balance.

The following examples of exercises describe how the exercise is performed while activating the deep stabilising muscles of the trunk and pelvis such as transverses. The following is an example of a trunk and Swiss ball exercise session completed in the training program.

A typical core stability, session completed throughout the training program.

a. Supine activation of transverses. Subject lies on back while holding lower stomach in. 10x10 second holds.
b. Supine cycle of legs. Lying flat on back, the subject cycles legs while activating transverses. 3 x10 each leg.
c. Static superman. Subject in bridge position, with the opposite hand and foot elevate in the air (the position of superman flying). 5 x 20 sec hold L/R
d. Reverse crunch. 4 x 15.
e. Back extensions and rotation lying on Swiss ball. 3 x 10
f. Sitting on a Swiss ball with 1 leg elevated. Subject activates transverses while a partner throws a medicine ball to them. 3 x 10
g. Lying on the back on a Swiss ball, the subject has legs apart and arms outstretched holding a 5-10kg weight plate above their heads. The subject then aims to slowly rotate side to side from the low back while maintaining a straight back or bridge position. 3 x 10.

Balance training program (eg, wobble board)

Stages of balance training

1. Basic stage. Challenge balance in exercises which are simple tasks such as single leg stationary balance and standing 2 legs on a wobble board.

2. Intermediate stage. Introduce more difficult balance activities requiring single leg dynamic balance, such as balancing on 1 leg while catching a football and single leg on a wobble board.

3. Advanced stage. Challenge single leg dynamic balance much further, while balancing single leg on a wobble board. Stand single leg on a wobble board while catching balls. Kick footballs to a partner while standing on a single leg on the wobble board.

A typical balance training session, including wobble board and single leg balancing exercises.

Aim: To improve the ability of the muscular system to assess where joints are in space and therefore improve balance capabilities.

a. Stand on the left foot in upright standing and complete 15 kicks with the right leg. 2 setsx15 repetitions
b. Hold the knee at 90 degrees for 30 seconds. 2 x 30 sec L/R
c. Hold the knee up and arms in a marking position. 2 x 30 sec L/R
d. Hold the knee up at 90 degrees and use the arms to run on the spot, changing speeds while maintaining single leg balance. 2 x 30 sec L/R
e. Stand on a wobble board on 2 legs and progress to 1 leg with the arms in the air. 3 x 30 sec L/R
f. Record how long the subject can stand in single leg standing on a wobble board without the board hitting the ground. 3 x 30 sec L/R
g. 20 handballs to a partner while balancing on a single leg in pairs. 2 X 20 Left hand/ Right hand
h. 45 degree to 270 degree spins in the air while standing on a single leg. 2 x 10 L/R at progressive degrees of spinning.