Physical Preparation for Netball – Part 2: Approaching Programme Design

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Introduction

Despite enjoying widespread popularity (notably in Australia and New Zealand, South Africa, the Caribbean nations and the United Kingdom) there is very little published research upon which to base training prescription for netball. This lack of studies to inform evidence-based practice is particularly unhelpful in view of the prevalence of lower limb injury among netball players at all levels (see Part 1 of this article in Issue No. 22). The following article summarises the data available for netball and reviews relevant findings from other sports. Recommendations are provided with regard to best practice for preparing netball players to successfully compete in the sport without undue risk of injury.

1. Approaching Physical Preparation for Netball

The stated objectives of physical preparation for netball – i.e. safeguarding against injury and improving performance – would appear to encompass three major aspects:

a. Strength training – including speed-strength development and plyometrics

b. Metabolic conditioning

c. Neuromuscular and movement skills training

In addition, targeted training interventions appear to be warranted in order to specifically address the types of injuries and associated risk factors characteristically observed in netball. As summarised in Part 1 of this article, common sites of injury documented in netball include ankle, knee, lower back and shoulder.

It has been highlighted by a study of netball players competing at national level that in order to be effective, physical preparation must not be conducted in isolation.[11] Training should rather be delivered in the context of the sport and the identified needs of each individual player, and undertaken in collaboration with coaching staff and medical support team. The importance of taking a multidimensional approach to physical preparation is also highlighted by the finding that strength training interventions which have been employed in isolation have reported little or no significant effect on measures of lower limb injury risk.[24] Similarly, movement skills instruction and feedback alone had limited effect on certain measures, specifically hip abduction and ground reaction forces.[24] Conversely, employing strength and movement skills training modalities in combination is found to have an additive effect, which was reflected in a much more significant positive impact across a wider range of kinetic and kinematic measures associated with lower limb injury risk.

Consistent with the primary objective of physical preparation for netball being guarding against injury, the logical first step when undertaking players' physical preparation is to conduct a musculoskeletal screening and dynamic profile.[11] This process should ideally be conducted jointly by both physiotherapist and strength and conditioning specialist. The initial musculoskeletal assessment will naturally be led by the physiotherapist, and will include standard clinical tests of passive joint integrity and range of motion. The second part – the dynamic profile – might then be led by the strength and conditioning specialist but jointly scored by both practitioners,

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and should consist of selected movement-based screens from the literature.[17] For example, one such screen that would appear to merit inclusion is the Star Excursion Balance Test.[6] This test requires the athlete to maintain their centre of balance within a fixed base of support (the supporting foot) whilst reaching out the opposite leg in various directions, which is reflective of balance demands on court. This dual approach including both clinical musculoskeletal and dynamic assessments will allow the identification of both mechanical factors (e.g. joint laxity, passive joint function) and functional instability under active conditions (e.g. impaired proprioception, balance, postural control) that have been implicated in lower limb injury in particular.[34]

Hypermobility has been identified as an intrinsic injury risk factor associated with increased injury rates among junior netball players.[53] This risk factor would be easily identified during players' initial musculoskeletal screening. Players exhibiting hypermobility around these joints would be susceptible to exposing connective tissue structures to joint ranges of motion in which they are placed under excessive strain. Such ligament laxity is also associated with decreased proprioception and kinaesthetic sense around the joints affected.[53] The interaction of these two factors readily explains the greater incidence of lower limb injury in particular suffered by netball players with hypermobility. Accordingly, where hypermobility is identified during the player's initial musculoskeletal screening there is a need for added emphasis on development of lower limb strength, postural control, proprioception and dynamic stabilisation in order to augment active stability provided to lower limb joints to compensate. Movement skills training will also help the player to avoid particular postures and lower limb biomechanics on court that place excessive stress on lower limb joint structures.[21,26,42]

2. Strength Training

2.1 Aims of Strength Training

Development of general strength for fundamental athletic movements – i.e. variations of squat, lunge movements etc – is necessary to underpin movement skills instruction with regard to 'safe' posture and lower limb alignment during activities on court. The integral role of strength training with respect to addressing lower limb injury risk has been highlighted by a recent study which identified that the effectiveness of movement instruction and feedback alone was limited in the absence of concurrent strength training.[24] It appears that development of lower limb force generating capabilities via strength training improves the athlete's capacity to make the necessary adjustments in posture and lower limb mechanics during athletic movements as instructed.[24] These findings underline the importance of concurrent strength training to support neuromuscular and movement skills training with regard to addressing lower limb injury risk factors.[28]

Following a period of general strength development appropriate to the requirements of the individual player, specific development of eccentric strength and eccentric speed-strength of lower limb kinetic chain would also appear necessary. There are obvious benefits to be derived from training these capacities as a means to develop the player's ability to absorb both impact forces when landing and torques generated during change of direction movements. To this end, speed-strength and plyometric exercises should be progressively introduced once the player reaches an appropriate stage in their physical development.

In addition to lower limb strength development for improved lower limb control and biomechanics, the other major objective of strength training for netball players is performance enhancement, which will necessarily include upper-body strength and speed-strength development. In addition to developing strength and speed-strength of agonist muscles involved in the passing and shooting movements that occur in netball, upper body strength development should also address the muscles that stabilise the shoulder girdle during these skill movements.

2.2 Exercise Selection

Players might be introduced to variations of the squat movement during their early preparation particular during off-season/preseason with the objective of developing general strength and postural control. As players' physical preparation progresses consideration must be given to the observation that training responses with respect to lower limb neuromuscular control appear to be movement task specific. Given that players rarely perform movement on court from an equal weight-bearing bilateral stance, it follows that there will therefore be a progression from bilateral strength training exercises to an increasing emphasis on exercises performed from a unilateral base of support. Exercises might include single-leg squat, backward and forward lunge with barbell, including variations with the barbell racked either across the front or the back of the shoulders. Variations of the step up exercise offer a means to develop gluteal muscle recruitment; this would appear important in view of the quadriceps/low back dominance often exhibited by female athletes.[22] Finally, to transfer strength development to multi-directional movements performed on court, lunge movements in a variety of directions; likewise variations of the step up exercises (e.g. lateral step up) might be considered.

From the point of view of developing strength and power for ball skills on court, upper body strength training exercises should include pushing lifts – for example variations of the push up as well as free weight exercises such as dumbbell bench and shoulder press. In addition pulling movements should also be included in players' upper body strength training. This is important for a variety of purposes including addressing/avoiding muscle imbalances, developing postural control around the shoulder girdle (scapular stabilisation) and the role of the mid back muscles in providing tension to the 'corset' of muscles that brace the trunk.[43]

Finally, alternate and single-limb exercises (for both upper and lower body) have advantages for concurrent development of postural control, lumbopelvic stability and torsional stability in particular.[44]

2.3 Speed-Strength Training

Jumping is a key movement for netball particularly for the positions that contest possession in the D area in the vicinity of the posts. Speed-strength exercises such as jump squats and Olympic-style lifts are proven modalities for developing vertical jump height and concentric power output.[23, 57] Versions of plyometric exercises that involve only the concentric part of the movement such as jump and bound movements executed from the floor or using a box without any preceding eccentric action can similarly be used to

Table 1 – Sample Off-Season/Early Preseason Training Cycle.

STRENGTH TRAINING	**Frequency:** 4 per week: 2 whole-body 1 upper-body 1 shoulder maintenance	**Example Whole-body Workout** 8RM; 3 Sets	**Upper-body Workout** 10RM; 5 Sets
	Intensity: 7-10RM (all lifts) **Volume:** 3-5 sets **Workout Format:** Circuit **Rest:** Short rest (<60sec) between lifts Core work (~2 mins) between (circuit) sets	Front Squat Push Up onto BOSU Ball Dumbbell Step Up with Hip Flexion Alternate Arm Cable Lat-Pulldown Dumbbell Split Squat Single-leg Good Morning	Suspended Row (feet supported on Swiss Ball) Incline DB Bench Press Alternate Arm Cable Lat-Pulldown Standing DB Shoulder-Press One-arm Dumbbell Row Bench Dips (feet supported on Swiss Ball)
Metabolic Conditioning		Long aerobic interval training. Combination of cross-training modes and running conditioning.	
Movement Skills Training		Instruction of fundamental movement skills. Self-paced. No read/reaction element.	

Table 2 – Sample Mid-Late Preseason Training Cycle.

STRENGTH TRAINING	**Frequency:** 3 per week: 2 whole-body 1 shoulder maintenance	**Example Whole-body Workout** 6RM; 3 Sets	**Upper-body Workout** 8RM; 3 Sets
	Intensity: 5-7RM multi-joint lifts 8RM assistance lifts **Volume:** 3-4 Sets **Workout Format:** 2x 3-lift Complexes **Rest:** Short rest (<60sec) between lifts Core work (~2 mins) between (complex) sets	Jump Squat Single-arm Cable Row Front Racked Backward Lunge Push Press Front Racked Barbell Step Up Single-leg Barbell Straight-Legged Deadlift	Cable External Rotation Alternate Arm Incline DB Bench Press Assisted Narrow-grip Chins Dumbbell Pull Over Prone Dumbbell Lateral Raise Alternate Arm Dumbbell Full Can Raise
Metabolic Conditioning		Progression aerobic interval to anaerobic interval training modes to repeated sprint conditioning late preseason. Combination of conditioning modes including skill-based games and conditioning drills at appropriate intensities.	
Movement Skills Training		Progression of technique development drills and instruction/development of acceleration mechanics mid-preseason, followed by introduction to higher velocity acceleration drills. Progression of change of direction movement skill drills, including simple reaction tasks, followed by gradual introduction of 'read/react' agility drills.	

Table 3 – Sample In-Season Training Cycle.

STRENGTH TRAINING	**Frequency:** 3 per week 2 whole-body 1 shoulder maintenance	**Example Whole-body Workout** 5RM; 3 Sets	**Upper-body Workout** 6RM; 3 Sets
	Intensity: 4-6RM (all lifts **Volume:** 3-4 sets **Workout Format:** 2x 3-lift Complexes **Rest:** Complete (self-selected) rest between consecutive lifts Core work (~2 mins) between (complex) sets	Power Clean ONE ARM Incline Dumbbell Bench Press Box-to-Box Drop Jump Loaded Split Bounds Single-leg Single-arm Dumbbell Row Front Racked Barbell Lateral Step Up	Prone Dumbbell 90-degree External Rotation Suspended Push Up on Rings Alternate Arm Cable-Reverse Fly Cable Diagonal Pulley ONE ARM Dumbbell Empty Can Raise Single-leg Cable Straight-arm Pulldown
Metabolic Conditioning		Cycling of aerobic interval training, anaerobic interval training and repeated sprint conditioning. Combination of conditioning games, skill-based conditioning drills, and movement-specific high-intensity conditioning drills, depending on respective block.	
Movement Skills Training		Progression to more challenging and context specific reactive agility drills and partner drills.	

develop concentric speed-strength for both bilateral and unilateral jump movements.

In terms of exercise selection, whilst developing power expression is important to a varying degree depending on the playing position, concentric power and reactive speed-strength are required in a variety of horizontal directions. This will necessitate speed-strength exercises that allow power to be developed in a horizontal as well as a vertical direction. Examples include variations of horizontal (bilateral and unilateral) jumps and bounds from a stationary start.[18]

Eccentric speed-strength is another important aspect which can be developed by using drop-and-hold landing movements, progressing drop height and moving from bilateral to unilateral landings in a variety of directions. The latter progressions in particular allow eccentric speed strength and dynamic stabilisation to be developed concurrently.

2.4 Plyometrics

Plyometrics offer development of both reactive strength (i.e. capacity for rapid transition from eccentric into concentric movement) and mechanical and neural elements of the stretch-shortening cycle (SSC) for both vertical and horizontal jumping and bounding movements on court. Players' plyometric training might follow a progression from slow SSC movements – for example countermovement jump – to fast SSC exercises such as drop jumps or cyclic bounding movements that emphasise short ground contact time. In much the same way as for strength training, plyometric training should also feature a progression from bilateral to unilateral jumping and bounding movements given the specific nature of training effects with respect to inter-muscular coordination.

3. Metabolic Conditioning

In view of the intermittent nature of activity in netball, it follows that metabolic conditioning for the sport should similarly follow an intermittent or interval framework. Metabolic conditioning for elite netball players might therefore comprise a combination of methods, including aerobic interval training, anaerobic interval training and repeated sprint conditioning.[15]

Practically through the course of the training year players' metabolic conditioning will encompass an array of conditioning modes. Cross training modes will feature predominantly during the off-season and early preseason; these sessions will also follow an interval format. However as the season approaches a combination of interval conditioning, tactical metabolic conditioning, and skill-based conditioning games will be employed to provide metabolic conditioning that is specific to the needs of the sport.[15]

Interval conditioning will tend to follow a progression from aerobic interval conditioning to anaerobic intervals and finally repeated sprint conditioning. Incorporating relevant movement skills into metabolic conditioning also provides the opportunity to reinforce correct and safe movement mechanics under conditions of fatigue. Tactical Metabolic Conditioning is another approach that may be used, which involves modelling conditioning upon observed patterns of work-to-rest identified from competitive matches[15] – albeit this will require prior investigation given the sparsity of data available for the sport. Finally, skill-based conditioning games not only incorporate relevant movement skills, ball skills and tactical elements but also offer advantages in terms of motivation and compliance.[15] That said, the effectiveness of this training mode is dependent on

imposing appropriate constraints.[50] Players should also be monitored during all sessions to objectively evaluate work rate, which requires access to the necessary equipment such as heart rate monitors.[15]

4. Neuromuscular and Movement Skills Training

The major objectives of movement skills training for netball are to instil safe movement strategies, improve players' athleticism and develop the change of direction movement abilities that underpin agility. As discussed in the first part of this article, targeted neuromuscular training interventions are critical in view of the deficits in lower limb control that are characteristically seen among female athletes.[17]

4.1 Postural Control

Postural control and balance abilities comprise input from visual, vestibular and somatosensory systems.[6] Postural control also involves the various elements that comprise lumbopelvic stability. A key element that contributes to lumbopelvic stability is the hip musculature of the supporting limb(s) during weight-bearing, which is particularly vital to postural control under both static and dynamic conditions. However, lumbopelvic stability also comprises the 'local' stabilising system of deep postural muscles and the 'corset' formed by abdominal muscles, low and mid back muscles and thoracolumbar fascia. The critical role played by the trunk muscles with respect to postural control is underlined by the observation that ability to control motion and orientation of the trunk during athletic movement impacts upon joint kinetics and kinematics throughout the lower limb kinetic chain – in particular at the knee joint but also the ankle joint.[29] Postural control and lumbopelvic stability similarly directly impact upon incidence of low back pain and injury.

Practically, 'sensorimotor training' to develop postural control or balance will consist of a range of single-limb support tasks that impose appropriate constraints to develop particular components of static balance either independently or in combination.[17] For example, single-limb balance tasks performed on a stable surface with eyes closed or turning the head are designed to specifically develop the vestibular input to postural control. Many practitioners progress the demand of the balance task by moving onto labile surfaces – such as balance disk or wobble board. A variety of single limb balance tasks with different constraints may be employed during athletes' training, however exercise selection should also feature relevant balance tasks on a stable surface similar to that found on court. One such balance task that might be considered is an adaptation of the Star Excursion Balance test.[6] The balance abilities required by this activity was reported to be relatively distinct from other measures of static balance in a study of female athletes, including female college soccer and basketball players.[6]

4.2 Dynamic Stabilisation

Dynamic stabilisation can be defined as the capacity of the athlete to maintain balance during the transition from motion to a static posture[7] – for example retaining postural control when landing from a hop or jump. This capability has obvious application for netball given that players are required to land and hold a stationary posture from a variety of hop, step, bound and jump movements within one and a half steps every time they take possession of the ball. Dynamic stabilisation is identified as a discrete ability that is distinct from static balance or postural control.[7] The aspects of executing a landing and decelerating the athlete's own momentum in order to come to a complete stop impose additional demands, in terms of strength and neuromuscular control, to those required for maintaining the athlete's centre of mass within a fixed base of support under static conditions.[59]

Developing dynamic stabilisation will require dedicated training in order to develop the feed-forward control capacities involved in landing tasks.[17] A study that employed a training intervention focussing on relevant exercises with elite female soccer players reported a significant reduction in a range of lower limb muscle and tendon injuries.[38] Further, this study identified that a dose-response relationship appeared to exist with dynamic stabilisation training with respect to injury reduction. That is, the greater the duration of sessions

Table 4 – Sample Peaking (In-Season) Training Cycle.

STRENGTH TRAINING	**Frequency:** 1 per week 1 whole body 1 shoulder maintenance	**Example Whole-body Workout** 4RM; 3 Sets	**Upper-body Workout** 6RM; 3 Sets
	Intensity: 4-5RM (all lifts) **Volume:** 3-4 Sets	Split Jerk Cable Resisted Alternate Knee/Shoulder Flexion Horizontal Bounds Barbell BOUND Step Up Ballistic Push Up (lower leg supported on BOSU Ball) Compass Bounds landing on BOSU Ball	Single-leg Cable 90-degree External-Rotation Dumbbell Pull-over with Alternating Hip Flexion Cable Reverse Diagonal Pulley CLOCK Push Up ONE ARM Bent-over Dumbbell Raise Prone DB Overhead Full Can Raise
	Workout Format: 2x 3-lift Complexes (whole body); Circuit (shoulder workout)		
	Rest: Complete rest between consecutive lifts Core work (~2 mins) between (complex) sets		
Metabolic Conditioning		Repeated sprint conditioning. Movement-specific high-intensity conditioning drills.	
Movement Skills Training		High-intensity game-related acceleration drills and game-related specific reactive agility and partner drills.	

with the training intervention during the study period, the greater the apparent reduction in injury incidence.[38]

A first step when training to develop dynamic stabilisation should involve instructing players on safe landing mechanics, including optimal lower limb alignment and posture. This has been observed to be an important part of successful interventions to reduce lower limb injury – notably knee injury – in female athletes.[28] Once these movement abilities have been developed under controlled conditions, such as dropping into a single-leg landing from a low box, training exercises can be progressed to incorporate constraints and movements similar to those experienced during game conditions. For example, the same themes in terms of safe landing postures and lower limb alignment can be transferred to drills that feature the variety of landing movements that players are observed to employ on court.[48]

4.3 Specific Movement Skills Development

Ultimately, the final progression for the bounding and landing drills described above is to execute these movements on court and incorporate intercepting a ball. This will facilitate best transfer of dynamic stabilisation and neuromuscular control to the specific jump-landing activities that feature in netball. Similarly, the evasive and tracking movements that feature in netball should also be developed in an appropriate way. Modifying change of direction movement technique via movement skills instruction has been shown to have the capacity to reduce potentially injurious loading on the knee joint.[10] As the athletes' movement skills advance, the drills employed to develop change of direction movement abilities should progressively incorporate the constraints and context in which these movements are executed on court. Similarly movement mechanics differ under pre-planned versus unanticipated conditions.[4] Progressions should therefore include withdrawing the ability for players to anticipate movement responses and incorporating the elements of decision making as encountered on court.[19]

5 Specific Training Interventions to Target Common Netball Injuries

Initial screening will help identify intrinsic injury risk factors for each individual player. This will include the player's injury history, hypermobility or joint laxity, conversely any deficits in mobility and stability, and imbalances in muscle function that may predispose the player to injury. Knowledge of common injuries and associated injury mechanisms will then help identify extrinsic risk factors associated with competing in the sport of netball.[16] Presented here is a summary of investigations involving netball players and data from other female team sports that highlight the injuries that netball players appear most predisposed to sustaining.

5.1 Ankle

Given the high incidence of ankle sprain injury – and high incidence of recurrence with this injury – it will be common for netball players at elite level to have a history of previous ankle sprain injury. Taping the lower limb and ankle joint is often employed particularly for players with previous ankle sprain injury as a means to augment proprioception due to the cutaneous stimulation provided.[33]

Afferent input from mechanoreceptors within the muscles associated with the ankle joint serve the dominant role in providing the athlete with a sense of joint position and kinaesthetic awareness.[30] Development of this afferent pathway is particularly crucial for players with previous ankle injury, which often disrupts sensory input from joint receptors – leading to an increased need for compensatory input. Appropriate strength training and neuromuscular training modes can provide development of proprioception provided by muscle mechanoreceptors. In accordance with this a variety of strength training and neuromuscular training interventions have been shown to improve measures of proprioception and ankle joint position sense specifically.[30]

Balance training including various exercises in a single-leg stance should similarly be used to develop the various systems that contribute to postural control and static balance. Exercises incorporating labile surfaces (wobble boards, balance disks etc) can be employed, however ultimately, exercises on a solid surface similar to that found on court should be used to help facilitate transfer of proprioception and neuromuscular training effects. There is also a need for specific development of dynamic stabilisation.[16] Feed-forward control of ankle stabilisers during the preparatory phase prior to touchdown during landing or stopping movements is suggested to be the more important factor in improving active stabilisation for those with chronic ankle stability.[30] This would appear to be a learned effect and thus amenable to development via repeated exposure to relevant movements in conjunction with appropriate coaching.

5.2 Knee

In view of the 'ACL-agonist' role of the hamstring muscles[26] and the plateau observed in hamstring strength scores among females following puberty in the absence of corrective strength training[2], it follows that hamstring strength development should receive appropriate focus in players' strength training. Appropriate (particularly unilateral) strength training is likewise identified as serving an important role in supporting development of lower limb neuromuscular control.[25]

Eccentric strength training is often employed for specific development of medial quadriceps (VMO) and patella tendon as part of the rehabilitation for patellar tendinopathy.[62] A range of training modes have been employed, including controlled eccentric knee flexion movements as well as rapid drop squats or drop jump landings.[58] Unilateral single-leg squat protocols have proven efficacy. These exercises typically performed on a decline surface, maintaining an upright posture with minimal forward torso lean and neutral lower limb alignment so that the supporting knee remains in line with the toes.[58]

A biomechanical analysis identified that employing a decline surface with a minimum angle of 15-degrees serves to specifically load the patella tendon, which appears to explain the superior effectiveness of decline squats in comparison to eccentric squats performed on a flat surface.[62] There does appear to be an optimal range of motion for the exercise – descending to a knee flexion angle of 60-degrees. Beyond this range forces placed upon the patellofemoral joint increase to a greater extent than patellar tendon forces.[62] In symptomatic athletes, the depth will initially be governed by pain experienced during the movement – it is typically recommended to work just into the range where the movement becomes painful.[58] Within the specific range of motion, progression can be achieved by adding external load, for example using dumbbells

held at the sides or supported upon the shoulders. Adding a 10kg load via a backpack was shown to increase knee movement of force by 23%.[62] It is important however that an upright torso posture is maintained when external loading is added, in order that appropriate moments of force through the lower limb joints are maintained during the movement.

Developing strength, endurance and neuromuscular control of the muscles that stabilise the trunk appears to be a critical aspect of reducing non-contact knee injury risk for netball players. Capacity to control trunk position and orientation has been implicated in ACL injury mechanism with females athletes[61] and a similar association is also reported between reduced lateral trunk strength and patellar tendinopathy.[9]

The hip muscles' role in providing lumbopelvic stability and controlling lower limb alignment in single-leg stance and athletic movements and its influence on knee joint loads has been identified as an important aspect in the mechanisms of both knee ligament injury[41] and patellar tendinopathy.[5,9] Much the same approach to training for static balance/postural control and specific development of dynamic stabilisation as that suggested for ankle injury prevention can achieve similar benefits for reducing non-contact knee injury risk. This has been shown to be an important aspect of training interventions to reduce rates of ACL injury among female athletes.[28] Similarly, this form of training has also been shown to reduce the incidence of patellar tendinopathy among elite female soccer players.[38]

Finally a key aspect of interventions to reduce lower limb injury is movement skills development, including instruction and reinforcement of 'safe' posture and lower limb alignment during landing and change of direction activities. Appropriate exercises with an emphasis on correct posture and technique can be incorporated into players' practice sessions. A study of female basketball players showed that a 20-minute movement preparation protocol performed prior to players' on court practice sessions effected significant improvements in lower limb kinetics and kinematics.[42] The effectiveness of this approach is underscored by a study of female soccer players that employed a movement preparation protocol in a similar way and likewise observed significant reductions in the incidence of non-contact ACL injury.[21]

5.3 Lower Back

Deficits identified during players' initial screening in any one of the components that contribute to lumbopelvic stability should be addressed in order to guard against low back pain and injury. For all players there is a need for development of strength, endurance and neuromuscular control of the muscles that stabilise the trunk. Training might include appropriate strength training exercises that emphasise bracing the trunk and controlling lumbopelvic posture in addition to more conventional core stability exercises performed from the floor and also labile surfaces and devices such as balance balls and stability balls. A postural stability and dynamic stabilisation training intervention was also associated with significant decreases in (non-contact) lower back injury in a sample of elite female soccer players.[38] It follows that this form of training would appear to be an important component of physical development with respect to protecting against low back pain and injury.

One key movement strategy for sparing the spine is to move from the hips in order that the players are better able to maintain a neutral spine position during movements on court. This is of course contingent on the athlete possessing the necessary hip mobility and strength to be able to move in this way. Accordingly, flexibility training and strength development for these hip muscles incorporating appropriate movements should be an important focus for netball players' training.

5.4 Shoulder

Regardless of whether there is a previous history of shoulder issues it seems prudent that a dedicated shoulder maintenance session is included in the training week for all players throughout the training year. Players' initial musculoskeletal and movement screening can be used to identify any risk factors to be addressed. In those with current or previous shoulder pain and instability the player's history and ongoing assessment can help guide their corrective training and shoulder development work.

Exercise selection will in general address the scapula stabiliser muscles and the rotator cuff. Specifically, middle and lower trapezius, rhomboids and serratus anterior are key muscles to be developed.[12,13] Exercises should similarly focus on developing kinaesthetic sense of scapula position. As for rotator cuff development, exercise selection should address all rotator cuff muscles; however the external rotators (predominantly infraspinatus and teres minor) appear to require special attention as these muscles are subjected to particular stress in throwing sports. Evidence of specific atrophy of the infraspinatus muscle accompanied by reduced external rotation strength scores in overhead striking athletes (beach volleyball players)[39] further suggests a need for specific development. This is likely to be the case particularly for those playing positions that contest for possession of the ball overhead, and execute one-handed over-arm passes, on a frequent basis.

There are a number of different exercises reported to successfully elicit significant activation of each of the four rotator cuff muscles either alone or in combination – see Escamilla *et al* (2009) for a review. Once isolated exercises for specific development of rotator cuff muscles have been introduced, more complex exercises can be included in players' training which allows greater force development.[20] Resistance in the form of either free weights (e.g. dumbbells) or cable machines are generally preferable for these exercises as they avoid the adverse length-tension relationship associated with resistance bands or tubing as well as providing greater ease of progressing load. Exercises for the scapula stabilisers should include rowing and pulling exercises that focus on retracting and adducting the scapula – for example cable and dumbbell rows, cable lat pull-down exercise, and both standard and supine variations of the pull up – as well as exercises that focus on controlled scapular protraction, such as the 'push up plus' and dumbbell pull over exercises.[12]

6 Conclusions

There would appear to be multiple components that should be incorporated into netball players' training. These include appropriate strength training and metabolic conditioning as well as neuromuscular training comprising elements of postural control, dynamic stabilisation and movement skill development. In addition, targeted training interventions have been

described that might be included to specifically address the types of injuries and associated risk factors characteristically observed in netball – including ankle, knee, low back and shoulder. There remains a critical need for further studies that specifically focus on netball, particularly at elite level.

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