An Evaluation of the NetballSmart Dynamic Warm-up in Youth Netball

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MSpEx (Hons, 1st Class)

A thesis submitted to Auckland University of Technology in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD)

2019
School of Sport and Recreation
Abstract

Netball is a popular, physically demanding female sport with a high risk of lower limb injury, particularly to the ankle and knee. Neuromuscular warm-up programmes can enhance modifiable factors that have been linked to performance and injury risk in both adult and youth team-sport athletes. The current evidence for this however is largely limited to male football. Additionally, as coaches are key to the successful implementation of these programmes, their feedback and further evidence of the performance benefits is needed. The overall purpose of this thesis was to determine if the recently developed NetballSmart Dynamic Warm-up can improve physical performance measures in female youth netball players. Additionally, there was a focus on exploring the role of the coach in the implementation of the warm-up.

To better understand the training needs of a female youth netball player, a physical performance profile of this group was determined. Differences were found in anthropometry, horizontal and vertical jump performance, balance, core strength, change of direction speed and sprint times between grades and playing positions (n=102; ES= 0.28 to 1.37). Results showed that players in higher grades performed physically better than lower grades. A physical performance profile could be used for talent identification and for guiding training programmes. Once a physical performance profile had been established, the same physical performance measures were used to investigate the effect of the NetballSmart Dynamic Warm-up on performance. Significant improvements in prone hold (β= 20.46 s; p= 0.01) and vertical jump (β= 6.73 cm; p= 0.01) were found in the intervention group (n= 45) compared to the control group (n= 36). In a sub-group study, the warm-up did not improve isokinetic knee flexor or extensor strength (60 %/s; p= 0.08-0.90) or change the hamstring to quadriceps ratio (mean difference= -0.02; p= 0.25). Both these studies provided preliminary evidence that some physical performance measures can be improved with this neuromuscular warm-up which will be useful when promoting the programme to coaches. Given the key role of the coach when including a new warm-up in training, coach experience of the warm-up and their knowledge and attitude to injury was evaluated through a coach survey.

The initial feedback on the warm-up provided by coaches was encouraging. Poor technique was perceived to be the most common injury risk factor (87%) in netball and the ankle was correctly reported as the most common lower limb injury (67%). The majority of coaches (93%) felt their personal coaching experience was sufficient to be able to coach the warm-up but reported barriers to the translation of the programme into the netball environment may cause delays in programme implementation and uptake. As coaches are a key influence in the adoption and maintenance of injury prevention
programmes, these barriers need to be addressed to ensure the sustainability and success of the warm-up programme.

Physical performance in youth netballers differs by playing grade and position and some performance factors can be improved with the implementation of the NetballSmart Dynamic Warm-up. It is recommended the warm-up be implemented in regular youth netball training guided by current and future coach feedback.
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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Chapters 3 to 6 of this thesis represent separate papers that have either been published or submitted to peer-reviewed journals. All co-authors have approved the inclusion of the joint work in this doctoral thesis.

................................................

Chloe Renee McKenzie

21st April 2019
# Co-Author Works

Table 1. Co-authored works.

<table>
<thead>
<tr>
<th>Chapter publication reference</th>
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CW: 5%  
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SB: 10% |
CW: 7.5%  
MB: 2.5%  
SW: 5% |
We, the undersigned, hereby agree to the percentages of participation to the chapters identified above:

**Supervisors**

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Acknowledgements

The last four years has been a journey of highs and lows, laughter and tears and I would not have made it to the end without the combined support of so many people in my life. Regardless of the role you had in my journey, this section is dedicated you.

To my supervisors Chris and Matt- I am truly grateful for your enduring support, guidance and encouragement. Chris, I greatly appreciate the time, energy and knowledge you gave to help me complete my thesis and thank you for always being so positive- it definitely got me through some tough times whether you knew it or not! Matt, thank you for your technical and academic expertise, but more importantly for believing in me and encouraging me to pursue a PhD in the first place. Simeon, thank you for your guidance and support on the thesis. To Scott, thank you for the time spent helping me in the lab, the coffees and advice.

I would like to acknowledge AUT and SPRINZ SKIPP group for providing me with the opportunity to complete my PhD and thank SPRINZ SKIPP group for support and funding for the conferences I have attended to present my research. Also, thank you to the research assistants who helped with data collection and the schools and netball players who were a part of this project, it would not have been possible without you.

To Mathias- you are my rock. I don't think I can ever thank you enough for your love, support, encouragement, positive words and pep talks! Thank you for helping me finish my thesis. You had the toughest job helping me stay on track, but I look forward to celebrating every bit of success with you. We shared every part of this journey and I am excited to start the next with you still by my side. Thank you for all that you are and all that you've done to help make me a better person. I love you.

To my family and friends, near and far- I am so grateful to have many wonderful people in my life. Thank you for your love, unconditional support and kind words, as well as providing a happy distraction to rest my mind outside of my research when I needed it. Mum, thank you for always being there- my number one supporter.

My life has been forever changed as a result of completing this PhD, thank you all again.
Ethics Approval

Ethical approval for this thesis research was granted by the Auckland University of Technology Ethics Committee (AUTEC) on 18th January 2016 for a period of three years:

- AUTEC: 15/458- Effects of a modified Fifa 11+ warm-up programme on physical performance in youth netballers.

Subsequent amendments approved by AUTEC:

- Data collection procedures- 7th April 2016
- Participant inclusion criteria- 14th July 2016
- Participant recruitment protocols and thesis title change- 10th April 2017
Chapter 1: Introduction and Rationale

The sport of netball

Based on an early version of basketball, the sport of netball was officially developed in England in 1901 (145). At that time, it was considered an acceptable sport for women to play as the physical restraint of the game appeared to conform to the then idea of femininity, despite it requiring vigorous activity (145). Netball is still considered a non-contact sport today, however the physicality and demands of the game have increased over time. Netball is played in a number of countries around the world, but due to its origins it is largely confined to the commonwealth countries (145). Following introduction to New Zealand (NZ) in 1906 (94), netball has grown to be the country’s most popular women’s sport with a reported 144,358 affiliated players in 2017 (92). It is also the number one sport played by girls in secondary schools (92).

To provide some context of the game, netball is an intermittent team sport played on a 30.5 x 15.25 m court which is divided into thirds (10.17 m long) (139). There is a “centre circle” in the middle third from which play begins (Figure 1). Two teams of seven players are on court at a time. Each player has a certain position restricting them to certain areas of the court. Positions are separated into centre court (centre [C], wing attack [WA], wing defence [WD]), shooters (goal shoot [GS], goal attack [GA]) and defenders (goal keep [GK], goal defence [GD]) (139). Each team has a goal post at either end of the court and shooters must score as many goals as possible within a 60-minute match (15-minute quarters) to win the game (one point is awarded per goal scored) (96).

Figure 1. Outline of a netball court with 7 players in starting positions

As netball is a dynamic and physically demanding game, it requires a high level of fitness, strength, speed and agility (84, 134). It involves acceleration and deceleration, cutting and changes of direction, jumping/landing and lunging; all while catching, passing and
shooting a ball (44). A unique rule that distinguishes the sport of netball from its origin (basketball) is the footwork rule. When a player lands with the ball in their hands, the first foot they land on is termed the “grounded foot” and this foot must stay on the ground or in the air until the player has released the ball. Re-grounding the grounded foot while still in possession of the ball is a “step”, which results in a turn-over of ball to the opposition. Equally, a hop, slide or drag of the grounded foot is classified as “stepping” and penalised infringing the footwork rule (95).

**Injuries in netball**

When receiving a pass at speed, a netball player must rapidly reduce horizontal velocity to come to a sudden stop to avoid violating the footwork rule. These abrupt decelerations impose high ground reaction forces (GRFs) on the lower body (139). Incorrect technique and insufficient neuromuscular control during deceleration and landing increases the risk of injury to the lower extremities (106). The most frequent cause of injury in netball is poor landing technique, collisions with players, being struck by the ball, or repetitive movement (i.e. jump/land, acceleration/deceleration, change of direction) (63). The locations of lower extremity injuries include the ankle (most common) (8, 106) and the knee (most expensive and often longest time out of the game) (84, 134, 139) with ligament sprains, bruising/contusions, and muscle strains reported as the most common injury types (63). The prevalence of injury during one season of netball in amateur and elite female netball players is estimated at between 54-57% (8, 106). More injuries occurred during match play than in training and the overall incidence of injury was 5.72 injuries / 1000 athlete hours in amateur netball players (106) and 9.08 injuries / 1000 athlete hours in elite netball players (8).

It has been well documented that female sports involving change of direction and jumping have a high incidence of knee injury (52). The most common knee injury in netball is an anterior cruciate ligament (ACL) rupture (139). An analysis into the mechanisms of 16 ACL injuries sustained in netball found that 13/16 occurred while landing from a jump; 6/16 occurred due to an unbalanced landing; 4/16 occurred during rapid breaking; and 12/16 occurred due to an apparent knee valgus collapse (135). The likelihood of sustaining an ACL injury in a non-contact sport such as netball is two to eight times greater for females than males (89). Higher peak knee valgus angles and lower peak hip and knee flexion in adult female basketball players (compared to males) during movements linked to non-contact ACL injury (sidestep, jump-land, shuttle run), may explain the increased risk (83). The increased susceptibility to ACL injury has also been found in the adolescent age-group (75, 111). The inability of female athletes to improve neuromuscular control after pubertal changes may add to the higher risk of ACL
injury in the adolescent years following the onset of puberty (111). Therefore, the combination of greater knee valgus angles, decreased hip and knee flexion, and higher GRFs during landing and cutting movements may account for the high lower extremity injury risk in netball (139).

**Physical performance measures and injury risk**

Physical performance measures such as movement technique, balance/proprioception and strength are associated with injury risk (3, 87, 101, 108). For example, a lack of strength or a strength imbalance can increase the risk of knee injury (89). Weakness about the knee, particularly in the hamstring muscles, has been shown to increase ACL injury risk in female athletes (87). Furthermore, eccentric strength deficits are of particular concern in ACL injury prevention as injuries occur more frequently during deceleration movements (97). Increased internal tibia rotation, combined with greater quadriceps activity and a low hamstring to quadriceps (H:Q) ratio, could also explain the higher incidence of non-contact ACL injuries in females (89). Furthermore, strength imbalances between the quadriceps and hamstrings muscle groups have been linked to hamstring strain injuries (101). Thus, strength deficits may lead to netballers adopting poor lower extremity landing mechanics leading to increased injury risk in netball specific landing tasks. Single leg balance has also been identified as a risk factor for injuries (3, 108). A shorter reach distance (≤ 77.5% of leg length) in the posterior-medial direction of the star excursion balance test increased the probability of sustaining an ankle sprain during netball (four times greater risk) (3). As physical performance measures have been shown to effect injury risk, tools that assess these performance measures could be used to help identify and reduce the risk of injury. As well as aiding injury prevention, physical performance data could also inform training for performance enhancement. With detailed information on physical performance characteristics it may be possible to identify factors, such as muscle weakness and poor movement mechanics, which contribute to injury risk and reduced performance. Efforts can then be focused on improving these modifiable physical characteristics (73).

**Physical performance, injury risk and performance profiling in youth athletes**

Adolescent youth play sport for many reasons, including psychosocial benefits of greater self-confidence, skill development, socialisation, teamwork and competition (26). However, the number of young people that continue playing sport at either a high level or recreational level into adulthood is relatively small (26, 74). Sport injury may contribute to the reduction in sport participation with 8% of youth reportedly dropping out of sport
annually because of injury (26). Sport is the leading cause of injury in youth, accounting for more than 30% of all youth injuries in some estimates (26). Therefore, due to high participation rates and high injury rates in this age group, it is important to ensure that youth athletes are provided with opportunities to enhance their physical development and reduce the risk of sport-related injury (43, 74). With this in mind it has been suggested that improving muscular strength should be a priority at all stages of youth development for males and females (73). Close associations have been found between muscular strength and running speed, muscular power, change of direction speed, jump ability and endurance (73). Additionally, as in adults, strength is an important factor for correct technique across a range of movements (73). Furthermore, mobility and stability have also been described as underpinning qualities in a player’s ability to perform fundamental movements (43). Thus, including muscular strength development and neuromuscular training in strength and conditioning programmes is not only crucial for enhancing sport performance, but also for reducing sport-related injury risk (43, 73). To enhance performance and reduce the risk of injury it is crucial that young netballers are equipped with adequate physical capabilities. There is some evidence in the published literature as to the physical demands and capabilities of netballers, specifically in youth (15, 126, 141, 142); however, further research is needed.

Research providing a physical performance profile, including anthropometric measures, of youth netball players could assist with physical development and performance enhancement. Physical performance profiling has been investigated in other sports (rugby league, football, Australian rules football, volleyball) (38, 40, 41, 47, 78) highlighting the knowledge of sport and position specific requirements can be useful for coaches to assist with training programs, ensuring athletes are physically prepared to perform successfully in a game (6, 142). In addition, performance profiles guiding physical development could also be used to aid talent identification (40). Several studies have reported physical activity profiles of adult netball players (6, 17, 22, 35, 36, 137), however there is limited observations of game demands in youth netball. There is currently no information on performance profiles of youth netball players in NZ, thus further research is needed to improve our understanding and assist netball and strength and conditioning coaches.

**Neuromuscular warm-up programmes**

Due to the high incidence of injury in netball, a broader promotion of injury prevention resources, combined with research into the effectiveness of these resources and how players can be encouraged to adopt appropriate injury prevention strategies, has been recommended (63). Injury prevention and performance enhancing programmes have
been implemented, and shown to be effective, in netball and other sports (24, 25, 48, 61, 67, 124). These programmes include neuromuscular training programmes (24, 61), sport-specific neuromuscular warm-up programmes (124), and sport-specific balance programmes (25).

A particular injury prevention programme that has reported success in reducing injuries is the FIFA 11+ (50, 76, 104, 124, 128). The FIFA 11+ is a structured, exercise-based neuromuscular warm-up programme designed to reduce injuries among female and male football players aged 14 years and older (104, 124). The warm-up has been shown to significantly reduce injury rates by 46% and decrease time-loss to injury by 29% when performed three times per week across a season of football (124). Furthermore, the FIFA 11+ warm-up can enhance physical performance (10). The warm-up has been shown to induce improvements in balance and stability, sprint, agility and vertical jump performance in football (4, 10, 65). This could, in part, explain possible underlying mechanisms of neuromuscular warm-up programmes linked to both performance and injury risk. The FIFA 11+ was developed by a group of international experts from FIFA's Medical Assessment and Research Centre (F-MARC), the Oslo Sports Trauma Research Centre and the Santa Monica Orthopedic and Sports Medicine Research Foundation (9). The structure and specific exercises included in the FIFA 11+ make it different to other previously implemented neuromuscular warm-up programmes. It has three parts that are performed in order (28). Part 1 involves running exercises at a slower pace, combined with active stretches and some partner contact in a controlled manner. Part 2 focuses on strength of the core and lower body, balance, plyometrics and agility. This section is made up of six different exercises, each with three levels of increasing difficulty. Part 3 involves running exercises at moderate to high speeds, combined with cutting movements. Exercises included in the programme are suggested to be “evidence-based” and/or “best practice” designed to prevent the most frequent types of injury in football (28). The developers of the programme identified core strength, neuromuscular control and balance, eccentric training of the hamstrings, plyometrics and agility training as important components of effective injury prevention; therefore, exercises such as prone holds, Nordic hamstring drops, and vertical jumps have been included in the warm-up programme (28). In addition to warming the body in preparation for training or games, adding these components and exercises into a warm-up should lead to improvements in core and lower body muscle strength, static, dynamic and reactive neuromuscular control, agility and jump techniques (28). A key element of the programme is using correct technique and proper movement, particularly correct posture and body control and alignment (28). For more details on the FIFA 11+, see the freely available instructions and manual on the official website (www.f-marc.com/11plus).
In 2016, largely due to the success of the FIFA 11+ programme, Netball NZ (NNZ) designed the NetballSmart Dynamic Warm-up based on the structure and exercises performed in the FIFA 11+ (See Appendix B for a summary of the NetballSmart Dynamic Warm-up). Slight modifications were made to the programme to make it more sport-specific to netball (93). NetballSmart is a collaboration between NNZ and the Accident Compensation Corporation (ACC) which is focused on decreasing the frequency and cost of injuries in netball players in NZ. In an effort to reduce injuries, the injury prevention warm-up was introduced as a part of the NetballSmart programme and NNZ has been promoting the warm-up across all of youth netball. Although similar warm-ups such as the FIFA 11+ have been shown to be successful in football there is no evidence of their effect in netball.

Evidence has suggested that neuromuscular injury prevention warm-up programmes have been successful in reducing injury risk and improving performance during controlled trials, however achieving adequate compliance to such programmes can be challenging (98). The most common Sports Injury Prevention model was originally introduced by van Mechelen and colleagues (1992) and more recently developed by Finch (2006) as the Translating Research into Injury Prevention Practice (TRIPP) framework (Table 2). The main limitation to the Sports Injury Prevention model addressed by the TRIPP model is the consideration for research leading to real-world sports injury prevention environments (31). The original model could provide evidence of effective prevention measures (147), however it did not ensure uptake or implementation of interventions (31). The addition of stages 5 and 6 of the TRIPP framework are of particular importance for injury prevention. These stages help to understand the barriers and facilitators to the implementation and sustainability of the programme (33). Since the development of the TRIPP framework, the Reach Efficacy Adoption Implementation Maintenance (RE-AIM) framework and the RE-AIM Sports Setting Matrix have also been introduced to attempt to identify the specific implementation components that influence the adoption, execution and maintenance of interventions (26, 33, 98).

A common factor in the successful implementation of an injury prevention programme in both frameworks is the role of the coach (123, 151). Compliance has been shown to influence efficacy of the FIFA 11+ programme, thus it is crucial that coaches are able to motivate their players to learn the programme and perform the exercises correctly and regularly (129). Coaches are responsible for encouraging and ensuring their players adopt and follow safe training practices (151). To ensure effective implementation of new injury prevention programmes adequate coach involvement, knowledge and education is vital (129, 151). Thus, evaluating the coach experience when implementing any new programme is crucial. Additionally, performance enhancing benefits have been identified
by coaches as a motivating factor to adopt and regularly deliver an injury prevention programme (123, 132). Thus, evidence the NetballSmart Dynamic Warm-up improves performance may increase coach uptake of the programme and consequently player adherence. Additionally, given the key role of the coach, their feedback and evaluation during the implementation of any new programme is crucial.

Table 2. Sports Injury Prevention frameworks.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Sports Injury Prevention model (147)</th>
<th>Translating Research into Injury Prevention Practice (TRIPP) (31)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Establish the extent of the problem</td>
<td>Injury Surveillance</td>
</tr>
<tr>
<td>2</td>
<td>Establish aetiology and mechanisms of injury</td>
<td>Establish aetiology and mechanisms of injury</td>
</tr>
<tr>
<td>3</td>
<td>Introduce preventative measures</td>
<td>Develop preventative measures</td>
</tr>
<tr>
<td>4</td>
<td>Assess their effectiveness by repeating Stage 1</td>
<td>“Ideal conditions”/scientific evaluation</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Describe intervention context to inform implementation strategies</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Evaluate effectiveness of preventative measures in implementation context.</td>
</tr>
</tbody>
</table>

**Purpose of the thesis**

The overall purpose of this thesis was to determine if the NetballSmart Dynamic Warm-up can improve physical performance measures in youth netball players.

**Significance of the research**

A better understanding of physical performance in youth netball and the potential benefits of neuromuscular warm-up will be valuable to coaches and players. As the physical condition of youth athletes has been linked to both performance and injury risk, a physical performance profile in youth netball players needs to be established. By determining a physical performance profile, modifiable factors that have been linked to both performance and injury risk (strength, balance, acceleration, deceleration and movement competency) can be evaluated in this group. Establishing this profile will help netball and strength and conditioning coaches understand factors that are most likely to influence performance and injury risk. Although the FIFA 11+ has been shown to improve physical performance and reduce injury risk, the efficacy of a neuromuscular warm-up is yet to be investigated in netball. By evaluating the effectiveness of the NetballSmart Dynamic Warm-up, it can be determined if the programme can improve physical performance measures linked to game performance and injury risk in youth netball players. Evidence the warm-up can improve physical performance is likely to increase coach uptake of the
programme and lead to greater player adherence. Furthermore, understanding coach knowledge and attitudes towards injury prevention, as well as experiences with the NetballSmart Dynamic Warm-up, may be beneficial for implementation strategies of the programme.

**Structure of the thesis**

Under the Auckland University of Technology's format 2, this thesis contains three sections and six chapters suitable for journal publication (Figure 2). The three sections progressively address the overall purpose of this thesis. The first section of the thesis (Chapter 2 and 3) is focused on a narrative review of literature evaluating the effect of neuromuscular warm-up programmes on physical performance measures in both adult and youth athletes and provides a physical performance profile of female youth netball players. The narrative review (Chapter 2) also highlights implications for implementation and compliance to injury prevention programmes and identifies the relevance and importance of evaluating the NetballSmart Dynamic Warm-up in female youth netball players. The physical performance profile of youth netball players in New Zealand (Chapter 3) investigates differences in physical performance capabilities between youth netball players competing in different grades and playing in different positions. The second section of the thesis (Chapters 4 and 5) investigates the effect of the NetballSmart Dynamic Warm-up programme on physical performance measures (Chapter 4) and isokinetic strength (Chapter 5) in female youth netball players after a seven-week intervention. The third section of the thesis (Chapter 6) investigates the experience of the coach in injury prevention programmes with a coach survey. Coach knowledge and attitudes towards injury prevention in netball and their experience and thoughts of the NetballSmart Dynamic Warm-up are evaluated.

The appendices contain supportive or technical material for the individual chapters and/or thesis as a whole. Table 3 provides a detailed summary of the purpose and rationale for each chapter, key findings, novel contributions and links between chapters.
Figure 2. Overview of the thesis structure
### Table 3. Summary of thesis chapters.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Chapter Title</th>
<th>Chapter Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction and Rationale</td>
<td><strong>Purpose:</strong> To provide background, rationale and significance to support the overall purpose of this thesis. An overview of the structure of the thesis is also presented.</td>
</tr>
</tbody>
</table>
| 2       | The Effect of Neuromuscular Warm-up Programmes on Physical Performance Measures: A Narrative Review | **Purpose:** Examine the current evidence for the effect of neuromuscular warm-up programmes on measures of physical performance.  
**Rationale for the purpose:** Neuromuscular warm-up programmes, in particular the FIFA 11+, have been shown to reduce injury risk; however, there is little evidence as to the mechanisms for this. Therefore, it is important to understand how such programmes effect modifiable factors that have been linked to both performance and injury risk.  
**Approach:** Narrative review.  
**Findings:** - Neuromuscular warm-up programmes improve some physical performance measures in team-sport athletes. - Most of the research on this topic was conducted in male football players with little evidence in female athletes and other sports. - Research involving female or youth athletes was focused on biomechanical/ movement changes and there was little evidence for other performance measures (e.g. jump, speed, strength).  
**Novel Contribution:** We have provided a comprehensive critique and synthesis of the current evidence identifying the effect of neuromuscular warm-up programmes on physical performance measures. |

**Prelude to Chapter 3:** Having first identified gaps in the literature regarding the effect of neuromuscular warm-up programmes on physical performance measures, the next step was to assess the physical performance capabilities of female youth netball players. A physical performance profile for the measures identified in the literature and linked to the demands of netball would help to
understand how a neuromuscular warm-up programme could improve modifiable factors linked to performance and injury risk.

<table>
<thead>
<tr>
<th>3</th>
<th>Performance Profiling of Female Youth Netball Players</th>
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<tr>
<td><strong>Purpose:</strong></td>
<td>Investigate the physical performance characteristics of New Zealand secondary school netball players to provide a physical performance profile. Secondly, to determine if there are differences between playing grades and playing positions.</td>
</tr>
<tr>
<td><strong>Rationale for the purpose:</strong></td>
<td>Identification of a physical performance profile can aid in understanding physical capabilities of players in relation to the demands of their specific sport. Little is known regarding physical characteristics of female youth netball players, playing positions and grades.</td>
</tr>
<tr>
<td><strong>Approach:</strong></td>
<td>Cross-sectional study.</td>
</tr>
<tr>
<td></td>
<td><strong>Findings:</strong></td>
</tr>
<tr>
<td></td>
<td>• Differences were found between playing grades. Higher grades demonstrated better physical ability than lower grades.</td>
</tr>
<tr>
<td></td>
<td>• Differences were found between playing positions of different grades.</td>
</tr>
<tr>
<td></td>
<td>• Differences were found between players with different anthropometric measures.</td>
</tr>
<tr>
<td></td>
<td><strong>Novel Contribution:</strong></td>
</tr>
<tr>
<td></td>
<td>This is the first study in youth netball to investigate physical performance and anthropometric differences between youth netball players of different playing grades and playing positions. It determined a profile for this age group and sport which could be useful to netball and strength and conditioning coaches for training and talent identification. Information can be used for position-specific training to help develop the capabilities needed for gameplay. We recommend a programme incorporating speed, change of direction ability and plyometrics for non-circle positions and a focus on developing horizontal force production for circle positions.</td>
</tr>
</tbody>
</table>

**Prelude to Chapter 4 and 5:**
A physical performance profile of youth netball players aged 13 to 14 years has been reported. This information can be used for physical development and talent identification. It is unknown if a neuromuscular warm-up, particularly the NetballSmart Dynamic Warm-up, can improve the identified performance measures.

Section 2
<table>
<thead>
<tr>
<th>4</th>
<th>The Effect of the NetballSmart Dynamic Warm-up on Physical Performance in Youth Netball Players</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose:</strong></td>
<td>Investigate the efficacy of the NetballSmart Dynamic Warm-up in improving physical performance measures in New Zealand secondary school netball players.</td>
</tr>
<tr>
<td><strong>Rationale for the purpose:</strong></td>
<td>The NetballSmart Dynamic Warm-up aims to enhance performance and prevent injuries; however there has been no studies investigating the effect of this warm-up. Little is known on the effect of a neuromuscular warm-up on performance in female youth netball players.</td>
</tr>
<tr>
<td><strong>Approach:</strong></td>
<td>Cluster randomized controlled trial.</td>
</tr>
<tr>
<td><strong>Findings:</strong></td>
<td>• The NetballSmart Dynamic Warm-up improves prone hold and vertical jump performance. • The NetballSmart Dynamic Warm-up should be included in regular netball trainings.</td>
</tr>
<tr>
<td><strong>Novel Contribution:</strong></td>
<td>This was the first study to investigate the effect of the NetballSmart Dynamic Warm-up. It provides preliminary evidence that some physical performance measures (vertical jump and prone hold) can be improved with the neuromuscular warm-up compared to a traditional warm-up. It is recommended that the warm-up be included in regular training.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5</th>
<th>The Effect of the NetballSmart Dynamic Warm-up on Isokinetic Knee Strength in Youth Netball Players</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose:</strong></td>
<td>Determine whether the NetballSmart Dynamic Warm-up can improve isokinetic knee strength in youth netball players.</td>
</tr>
<tr>
<td><strong>Rationale for the purpose:</strong></td>
<td>Adequate knee strength is needed to perform successfully in netball given the demands of the game. The knee is also a common site of injury in netball and weakness about the knee is associated with several knee injuries in female athletes. There is currently no research investigating the effect of the NetballSmart Dynamic Warm-up on knee strength.</td>
</tr>
<tr>
<td><strong>Approach:</strong></td>
<td>Single group intervention.</td>
</tr>
<tr>
<td><strong>Findings:</strong></td>
<td>• The NetballSmart dynamic Warm-up did not improve knee peak torque or change angle of peak torque.</td>
</tr>
</tbody>
</table>
- There were no significant changes found in the hamstring to quadriceps ratio.

**Novel Contribution:**
Evidence that when performed two to three times per week, the NetballSmart Dynamic Warm-up does not improve knee strength in youth netball players.

**Prelude to Chapter 6:**
Having investigated the effect of the NetballSmart Dynamic Warm-up, further evaluation was undertaken to consider the level of coach knowledge and their attitudes towards the warm-up and injury prevention in netball. Their experiences with the warm-up must be considered to provide further insight to assist the implementation of the programme.

## Section 3

### Implementation of the NetballSmart Dynamic Warm-up: The Role of the Coach

**Publication resulting from Chapter:**

**Purpose:**
Examine coach knowledge and attitudes towards injury and injury prevention in netball. Secondly, evaluate the experiences of the NetballSmart Dynamic Warm-up amongst coaches delivering the programme.

**Rationale for the purpose:**
Coaches are a key part in the successful implementation and sustainability of injury prevention programmes. Since the development of the NetballSmart Dynamic Warm-up in NZ there has been no research into the adoption and maintenance of the programme.

**Approach:**
Cross-sectional survey design using a mixed method approach.

**Findings:**
- Poor technique was perceived to be the most common injury risk factor in netball, and almost all coaches believed that a warm-up can reduce injuries. The ankle was correctly reported as the most common lower limb injury.
- Experienced coaches or coaches who were also netball players did not have better knowledge of injuries.
- Most coaches felt their personal coaching experience was sufficient to be able to coach the warm-up.
- Most coaches reported observing improvements in player ability after using the warm-up.
- A significantly higher proportion of coaches who were also netball players reported they would deliver the warm-up one to two times per week.
Regarding their experience of the NetballSmart warm-up three dominant themes were identified in the qualitative data: 1) the importance of coach education and understanding of injury prevention; 2) long-term player development; and 3) practical implementation of the NetballSmart Dynamic Warm-up.

**Novel Contribution:**
Initial coach feedback on the NetballSmart Dynamic Warm-up, as well as current coach knowledge and attitudes towards injury and injury prevention in netball, has been reported. The feedback from coaches was generally positive but highlighted some barriers to the translation of the programme into the netball environment which need to be addressed to ensure its success and sustainability.

<table>
<thead>
<tr>
<th>7</th>
<th>Discussion &amp; Conclusion</th>
<th>Purpose:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>To discuss the key findings across the thesis as a whole, summarise the novel contributions made, identify the limitations of the thesis and make recommendations for future research.</td>
</tr>
</tbody>
</table>
Section 1: Neuromuscular Warm-up Programmes and Physical Performance in Youth Athletes
Chapter 2: The Effect of Neuromuscular Warm-up Programmes on Physical Performance Measures: A Narrative Review

This chapter has been embargoed and will only be released on the

18-October-2020
Chapter 3: Performance Profiling of Female Youth Netball Players

This chapter comprises the following paper published in *Journal of Strength and Conditioning Research*.

**Reference:**


**Overview**

The purpose of this study was to investigate the physical performance characteristics of New Zealand secondary school netball players to provide a physical performance profile and determine if there were differences between playing grade and playing positions for this group. A total of 102 female netball players (mean ±SD: age 13.3 ±0.50 y, height 166.95 ±5.72 cm, body mass 60.94 ±12.80 kg) participated in this study. Measurements included anthropometry, horizontal and vertical jump performance, balance, core strength, change of direction speed and split sprint times. Magnitude-based inferences were used to determine differences in all measures. Grade one players jumped further and higher (ES= 0.41 to 1.37) and ran faster with small to moderate differences. They demonstrated faster change of direction speed (ES= -0.73 to -1.31), greater core strength (ES= 0.28 to 1.17), and a faster time-to-stabilisation (ES= -0.69). Grade two circle players jumped further (ES= -0.29), compared to non-circle players who jumped higher (ES= 0.35). Non-circle players had faster sprint and change of direction speed (ES= -0.33 to -0.55) and measures of balance (ES= -0.47 to 0.55). Grade one circle players were found to be faster over 20 m (ES= 0.75). The results of this study showed differences in the physical performance capabilities between youth netball players competing in different grades, as well as differences between playing positions. These findings have provided a physical performance profile of female youth netball players in New Zealand, suggesting that physical performance measures could be used for position-specific training and talent identification and selection.

**Introduction**

Netball is an intermittent team sport that is popular among females in the commonwealth countries, with more than 145,000 affiliated players in New Zealand (NZ) alone (17, 91). It is a highly physical non-contact sport requiring speed, anaerobic power, changes of
direction, abrupt deceleration, jumping and landing; as well as tactical awareness and ball skill (44). Netball is played on a court 30.5 m × 15.25 m which is split into thirds (17). The thirds create spatial restrictions subsequently influencing the task constraints for each of the seven positions on court (17). Task constraints, including rebounding, guarding, off-ball guarding, defending, sprinting, jogging and shuffling, for each position have been shown to influence the physiological demands and activity profiles of adult players during a game of netball (36). The seven positions in a game of netball include mid-court positions (centre (C), wing attack (WA), wing defence (WD)), shooting positions (goal shoot (GS), goal attack (GA)), and defence positions (goal keep (GK), goal defence (GD)). Positional groups in this study were divided into circle (GK, GS, GA, GD) and non-circle (C, WA, WD) players.

The physiological demands placed on players in various sports and across different positions is of interest to strength and conditioning coaches. Information regarding sport and position specific requirements can be applied directly by strength and conditioning coaches to assist them in the design and implementation of training programs, to ensure athletes are prepared to withstand the physical requirements and perform successfully in a game (6, 142). Several studies have reported the physiological demands and activity profiles of adult netball players (6, 17, 22, 35, 36, 137). Video footage and a supporting computer analysis system has been used to measure specific netball movements during a game of netball (22, 36). It was found that mid-court players (GD/WD/C/WA/GA) performed more jogging, running and sprinting activities compared to predominant circle players (GS/GK) (36). The C position also travelled further and had the highest mean percentage time spent in active activity than both GK and GS positions (22, 36). It was also found that GS performed far less jumps (vertical) than any other position (36). Other studies have used accelerometers or a radio frequency-based athlete tracking system to measure player load and movement frequency in netball (6, 17, 35, 137). The position with the greatest player load was found to be C (6, 17, 35) with GS having the lowest player load than all other positions (17, 35), as well as performing movement combinations that were very different to all the other positions (137). The greatest contributor to total match load for C was jogging, compared to shuffling for GS (6). The C position was also found to have the greatest level of activity in all planes of movement. Pairwise comparisons between playing positions of elite-level netball players found that GD and GS were most dissimilar, with only the WA, GA and GD playing positions being closely related (137). Additional research between playing positions has also been conducted in other intermittent team sports, such as rugby league and soccer (41, 47). It has been shown that there are specific roles in team sports, and these roles have position-specific game demands; therefore, the need for position specific components in training and strength and conditioning is important to ensure player success (36).
Knowledge of sport-specific game-demands can help to create performance profiles for different sports, as each sport and its’ positions could be seen to be characterized by a different athletic profile (47). The use of physiological and anthropometric assessments of athletes to build physical performance profiles has been investigated in several sports, including netball (126), rugby league (40, 41), football (47, 78), Australian rules football (116) and volleyball (38). Furthermore, it has been suggested that performance profiles could assist with team selection or talent identification of athletes, as well as determining starting and non-starting players (i.e. players selected to participate in a team or starting line-up) (40, 78, 126). Typically, physiological and anthropometric measures have also been found to improve with an increase in playing level (38, 41, 126). Knowledge of the differences in physical characteristics between junior and senior players could impact junior athlete development (126). Significant differences were found in physiological measures between junior elite and sub-elite rugby league players (40). Junior elite players were found to be superior in speed, change of direction speed, vertical jump height and estimated maximal aerobic capacity (VO2max) compared to their sub-elite counterparts. Elite Australian netball players were found to be significantly taller, faster and had superior lower leg power and greater running capacity than lower playing levels (sub-elite, regional, under 19 and under 17) (126).

Despite the importance of physical qualities for match performance, there are limited studies investigating physical profiles in youth netball, specifically in NZ. Physiological and anthropometric differences have been found across three age categories in a regional netball academy in the United Kingdom (141), and height, body mass and physical characteristics have been shown to differ between positions in youth netball (142). Additionally, Thomas et al. (2016) have reported some initial normative performance data for youth female netballers. Therefore, the purposes of this study were to provide a physical performance profile and determine if there are differences between level of performance (playing grade) and/or playing positions (circle versus non-circle players) in NZ secondary school netball players. There is currently limited data on this topic and identifying performance profiles and positional demands could potentially assist with selection, training, coaching and player development.

Methods

Experimental approach to the problem

A cross-sectional study design was used to investigate physical performance measures in female youth netball players. This was achieved by conducting various physical performance tests and determining differences between playing grade and playing position. All testing was conducted during the early competitive phase of the netball
season. All testing was conducted on-site at the involved secondary schools, with an average of 90 minutes to complete the testing battery. The location, time constraint and previous studies influenced the selection of tests included in the field-testing battery.

Subjects

A total of 102 female youth netball players (mean ±SD: age 13.3 ±0.50 y, height 166.95 ±5.72 cm, body mass 60.94 ±12.80 kg) participated in this study. Participants were recruited through local secondary schools. All participants were training and competing in a secondary school netball program and were healthy and free from injury in the last six months. As the structure of the netball program was similar for all grades, the participants were involved in netball-specific training twice a week with one competitive game. Training and game duration were the same for all participants. The participants had no previous resistance or neuromuscular training. Prior to participation, all participants were informed of the benefits and risks of the investigation before signing an institutional approved informed assent document to participate in the study. As all participants were under the age of 18 years, parental or guardian consent was also required by signing an institutional approved informed consent document. This study was approved by the Auckland University of Technology Ethics Committee.

Procedures

The selected measures and corresponding tests for this study were balance (Modified Star Excursion Test), split sprint times (2 to 20 m straight line sprint), change of direction speed (T-test), vertical and horizontal jump performance, core strength (prone hold), and lower body dynamic stability (time-to-stabilisation (TTS) landing). In addition, body mass, height, playing position and playing level were recorded. Participants performed a 10-minute standardised warm-up that replicated a generic netball warm-up, consisting of jogging, fast dynamic movement (butt kicks, high knees, side-step, grape-vine), slow dynamic movement (variation of bodyweight squats, lunges, hurdle walk, leg swings), and finished with low-intensity sprint drills and low volume plyometric exercises (vertical and horizontal jumps). They were then split into groups as the testing battery followed a rotational format; therefore, we did not control for the order of exercises. Three recorded trials were performed at each testing station after warm-up and test familiarisation and the best of these three trials was used for analysis. All tests were selected due to their relevance to common game-related activity and movements that have been identified during a game of netball (36).
**Vertical Jump**

An AMTI portable force plate (Advanced Mechanical Technology, Inc. Watertown, MA) was used to assess vertical jump height (400 Hz sampling rate). Participants were required to stand in the centre of the force plate with their feet hip width apart and hands on their hips. They were then asked to perform a maximal countermovement jump (CMJ), jumping and landing on two feet, keeping their lower limbs extended during the flight phase of the jump. Participants were allowed three familiarisation jumps before data was collected. Jump height was then determined by finding the total flight time in a custom-made LabVIEW program (National Instruments, 2014, Auckland, NZ) and inserting into an equation previously used by Moir (2008). The equation is as follows: time in the air \( \text{jump height} = \frac{1}{2} g \left(\frac{t}{2}\right)^2 \), where \( g = 9.81 \text{ m sec}^{-2} \) and \( t = \text{time in air} \). Participants performed three trials with 30 seconds rest between trials.

**Horizontal Jump**

Participants were asked to stand with their feet flat on the ground with their toes behind a line marked perpendicular to a measuring tape (0 cm mark). They were then asked to jump as far forward as possible, using arm swing and landing on both feet. The participants were required to stick their landing and stay in the end position until the measurement had been taken. Three familiarisation jumps were allowed to ensure they applied the correct movement pattern. Jump distance was measured from the start line (0 cm mark) to the heel of the back foot upon landing. If participants did not stick the two-foot landing it was considered a “non-jump” and they were required to repeat the jump until three successful jumps were recorded, with 30 seconds rest between trials.

**Time-to-stabilisation**

Similar to previous methods (119), participants were first assessed for a two-foot maximal vertical jump height using a Vertec (Swift Performance Equipment, Queensland, AUS) which was placed directly over the centre point of an AMTI portable force plate (Advanced Mechanical Technology, Inc. Watertown, MA). Once maximum jump height had been established, the plastic fingers of the Vertec were set at 50% of this value. This created an individual jump height target to control for jump height during each TTS test (119). To begin the TTS test, the participants were asked to stand behind a marked line 20 cm back from the centre of the force plate. Then, applying a two-footed CMJ, they were asked to jump and reach their individual jump height target with their fingertips and land single legged on their right foot with their hands on their hips. The participant had to stabilise and assume this balanced landing position as quickly as possible without any additional motion (i.e. hopping, swaying or letting the left foot touch
the force plate). They were required to hold this stabilised position for 10 seconds. If a participant fell or lost balance the test was repeated. Participants were allowed at least three familiarisation jumps before data collection. Participants were required to repeat the jump until three successful jumps were recorded, with 30 seconds rest between trials. The time-to-stabilisation was determined in a custom-made LabVIEW program (National Instruments, 2014, Auckland, NZ) from the time of initial landing contact until they stabilised within 5% of their body mass (144).

Prone Hold

Participants assumed a prone hold position with their elbows and forearms on the ground, hands grasped, feet approximately hip width apart, head facing towards the ground and body straight with no arching or bowing in the lower back. The participant was required to maintain this position for as long as possible. The test was stopped if the participant excessively arched or bowed their lower back. The maximum time the participant maintained a correct position was recorded. This test was performed once.

Speed

Split sprint times were measured with a Radar Gun (Stalker ATS II, Applied Concepts Inc., Richardson, TX) across distances of 2, 5, 10, 15 and 20 m. Participants were asked to start from a still, split stance position 2 m directly in front of the radar gun. Participants were encouraged to sprint as fast as they could for each trial, completing a total of three recorded trials. Data was then cut using the Stalker ATS II software program (Version 5.0). In each trial, an acceleration run was determined by eliminating any data that had a zero value and by cutting each trial at the point where speed began to decrease. All cut files were then analysed in a custom-made LabVIEW program (National Instruments, 2014, Auckland, NZ) to find split times at each distance.

Change of direction speed

A T-test was used to measure change of direction speed (122). A different change of direction test has been used in previous netball literature (141, 142); however, this test was chosen as the movements required to complete the test are very similar to the physical movement demands of netball, including forward sprinting, side shuffling (left and right), and backpedalling (36). Cones were set up to resemble a ‘T’ shape. A marked start/finish line with timing gates, placed at approximate hip height for all participants, (Swift Performance Equipment, Queensland, AUS) was set up on court. The test started by sprinting forward, activating the timing gates, to the top of the T (5 m). From there participants side-shuffled to the left (5 m), back to the right past the centre cone (10 m),
shuffled left again back to the centre cone (5 m), and then backpedalled through the timing gates. The test was repeated three times as fast as possible in the same direction, with one-minute rest between trials.

**Balance**

A modified Star Excursion Balance Test (SEBT) was used to measure single leg balance and proprioception using a composite score. Each participant completed the SEBT following the methodology as outlined in a previous study (30). Each participant was allowed seven trials for each direction. The first four trials were practice followed by three recorded trials (117). The participants’ right lower limb measurement, from the most distal end of the anterior superior iliac spine to the centre of the malleolus, were taken and recorded for the composite score (30). The test was only performed on the right side for all participants due to time constraints. A SEBT composite score was calculated by dividing the maximum reach distance in the anterior (A), posterolateral (PL) and posteromedial (PM) directions by 3 times the limb length (LL) of the individual participant, then multiplied by 100 ((A + PL + PM)/(LL x 3) x100) (30).

**Statistical analysis**

Normality was tested using the Shapiro-Wilk test and by visual review of histogram graphs (SPSS, version 22). A spreadsheet for comparing the means of two groups (controlled trials, crossovers and time series) was used to log-transform the data prior to analysis and derive magnitude based qualitative inferences as to the true difference between groups (57). Within-session reliability of all test variables, other than prone hold which was a single maximal-effort test, were calculated through an online spreadsheet (60). Reliability was assessed using the interclass correlation coefficient (ICC) and typical error (TE) of measurement. To determine the magnitude of the ICC, threshold values were 0.1 (low), 0.3 (moderate), 0.5 (high), 0.7 (very high), 0.9 (nearly perfect), 1.0 (perfect) (59). The group comparisons included comparing year 9 grade one players to lower grade year 9 players and comparing players by position (circle vs non-circle) within grade one (year 9) and grade two (year 9 and year 10 combined). A Cohen’s d effect size (ES) of 0.2 was used as the threshold for substantial differences (58). Inferences were based on the likelihood the true value of the ES was greater than 0.2 using the following scale: 25-75% possibly, >75% likely, >95% very likely, >99.5% most likely (58). Where the effect had a >5% probability of being substantially negative or substantially positive the inference was stated as unclear. Magnitudes of observed ES’s were interpreted based on the following scale: 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large), and their inverse (58).
Results

Differences between playing grades

Within session reliability is presented in Table 5. Results, including raw outcomes and differences in performance between players from different grades can be seen in Table 6 and Table 7. Grade one players demonstrated greater jump ability than lower grade players with moderate (ES= 0.85) to large (ES= 1.37) differences in horizontal jump distance, and small (ES= 0.41) to moderate (ES= 0.61) differences in vertical jump height. Grade one players were also faster with moderate (15 m, ES= -0.68) to small (ES= -0.25 to -0.58) differences in sprint times, compared to grade two players. There were also moderate (ES= -0.69 and -0.75) differences in 20 m and 15 m sprint times between grade one and grade four players, while the differences in sprint times over shorter distances were unclear. Grade one players recorded faster times for the T-test with moderate (ES= -0.73) to large (ES= -1.31) differences. Grade one players also performed better on the TTS test (ES= -0.69) than grade four players, while other comparisons for TTS and all SEBT comparisons were unclear. There was a small difference (ES= 0.28) found in the prone hold between grade one and two players, and a moderate difference (ES= 1.17) between grade one and four players.
## Table 5. Reliability statistics by grade and all groups for all test variables.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Year 9 Grade one (n= 26)</th>
<th>Year 9 Grade two (n= 42)</th>
<th>Year 9 Grade four (n= 8)</th>
<th>Year 10 Grade two (n= 26)</th>
<th>All Groups (n= 102)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC (90% CI) TE (90% CI)</td>
<td>ICC (90% CI) TE (90% CI)</td>
<td>ICC (90% CI) TE (90% CI)</td>
<td>ICC (90% CI) TE (90% CI)</td>
<td>ICC (90% CI) TE (90% CI)</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>0.87 (0.78-0.93) 0.38 (0.32-0.46)</td>
<td>0.87 (0.81-0.92) 0.36 (0.32-0.43)</td>
<td>0.97 (0.91-0.99) 0.21 (0.16-0.36)</td>
<td>0.90 (0.84-0.95) 0.32 (0.27-0.40)</td>
<td>0.91 (0.88-0.94) 0.30 (0.27-0.33)</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>0.69 (0.52-0.82) 0.57 (0.48-0.70)</td>
<td>0.59 (0.42-0.72) 0.65 (0.57-0.77)</td>
<td>0.80 (0.49-0.94) 0.52 (0.40-0.87)</td>
<td>0.60 (0.39-0.77) 0.64 (0.54-0.81)</td>
<td>0.65 (0.55-0.74) 0.60 (0.55-0.67)</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>0.66 (0.48-0.80) 0.59 (0.50-0.73)</td>
<td>0.68 (0.54-0.79) 0.57 (0.50-0.68)</td>
<td>0.84 (0.59-0.95) 0.46 (0.36-0.77)</td>
<td>0.57 (0.34-0.74) 0.67 (0.56-0.84)</td>
<td>0.69 (0.59-0.77) 0.57 (0.51-0.63)</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>0.58 (0.37-0.74) 0.66 (0.56-0.82)</td>
<td>0.56 (0.39-0.70) 0.67 (0.58-0.79)</td>
<td>0.80 (0.50-0.94) 0.52 (0.40-0.86)</td>
<td>0.42 (0.16-0.96) 0.77 (0.64-0.97)</td>
<td>0.57 (0.45-0.67) 0.66 (0.60-0.74)</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>0.33 (0.09-0.56) 0.83 (0.70-1.02)</td>
<td>0.36 (0.16-0.54) 0.81 (0.70-0.95)</td>
<td>0.72 (0.36-0.91) 0.59 (0.46-0.99)</td>
<td>(-0.07-0.46) 0.91 (0.75-1.14)</td>
<td>0.36 (0.23-0.49) 0.80 (0.73-0.90)</td>
</tr>
<tr>
<td>Sprint 2m (s)</td>
<td>0.24 (0.74-1.08) 0.88 (0.74-1.08)</td>
<td>-0.02 (0.38-0.19) 0.91 (0.79-1.08)</td>
<td>0.65 (0.25-0.89) 0.65 (0.50-1.09)</td>
<td>-0.13-0.41) 0.78 (0.78-1.17)</td>
<td>0.26 (0.13-0.40) 0.86 (0.78-0.97)</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>0.92 (0.86-0.96) 0.29 (0.25-0.36)</td>
<td>0.89 (0.83-0.93) 0.34 (0.29-0.40)</td>
<td>0.74 (0.38-0.92) 0.58 (0.45-0.97)</td>
<td>0.85 (0.74-0.92) 0.40 (0.34-0.52)</td>
<td>0.74 (0.66-0.81) 0.51 (0.46-0.57)</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>0.87 (0.79-0.93) 0.37 (0.31-0.45)</td>
<td>0.85 (0.75-0.91) 0.39 (0.34-0.46)</td>
<td>0.79 (0.49-0.94) 0.53 (0.41-0.88)</td>
<td>0.81 (0.69-0.89) 0.45 (0.38-0.56)</td>
<td>0.81 (0.81-0.90) 0.38 (0.34-0.42)</td>
</tr>
<tr>
<td>SEBT (composite score)-Anterior</td>
<td>0.79 (0.66-0.88) 0.47 (0.40-0.59)</td>
<td>0.82 (0.73-0.89) 0.43 (0.38-0.52)</td>
<td>0.77 (0.45-0.93) 0.55 (0.42-0.91)</td>
<td>0.90 (0.83-0.95) 0.30 (0.27-0.41)</td>
<td>0.82 (0.76-0.87) 0.43 (0.39-0.48)</td>
</tr>
<tr>
<td>SEBT (composite score)-Posterolateral</td>
<td>0.69 (0.51-0.82) 0.57 (0.49-0.72)</td>
<td>0.81 (0.71-0.88) 0.45 (0.39-0.53)</td>
<td>0.92 (0.78-0.98) 0.34 (0.26-0.57)</td>
<td>0.92 (0.86-0.96) 0.30 (0.25-0.37)</td>
<td>0.79 (0.72-0.95) 0.47 (0.42-0.52)</td>
</tr>
<tr>
<td>SEBT (composite score)-Posteromedial</td>
<td>0.81 (0.68-0.89) 0.45 (0.39-0.57)</td>
<td>0.82 (0.73-0.89) 0.43 (0.37-0.52)</td>
<td>0.81 (0.51-0.94) 0.51 (0.40-0.85)</td>
<td>0.90 (0.82-0.94) 0.33 (0.28-0.42)</td>
<td>0.84 (0.78-0.88) 0.41 (0.37-0.46)</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>0.41 (0.18-0.62) 0.78 (0.66-0.96)</td>
<td>0.23 (0.04-0.43) 0.88 (0.77-1.04)</td>
<td>-0.27 (0.04-0.43) 0.93 (0.70-1.50)</td>
<td>-0.27 (0.08-0.55) 0.83 (0.71-1.04)</td>
<td>0.31 (0.17-0.45) 0.83 (0.76-0.94)</td>
</tr>
</tbody>
</table>

ICC=intraclass correlation coefficient; TE= typical error; CI= confidence interval; SEBT=star excursion balance test; TTS=time-to-stabilisation
Table 6. Physical performance characteristics of Grade one and Grade two female netball players.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Grade one (n= 26) mean ±SD</th>
<th>Grade two (n= 42) mean ±SD</th>
<th>Mean Difference: ES (90% CI)</th>
<th>ES Magnitude</th>
<th>Qualitative Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone Hold (s)</td>
<td>93.81 ±40.00</td>
<td>89.79 ±59.90</td>
<td>0.28 (-0.11 to 0.68)</td>
<td>small</td>
<td>possibly</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>13.34 ±0.79</td>
<td>13.99 ±0.94</td>
<td>-0.73 (-1.14 to -0.33)</td>
<td>moderate</td>
<td>very likely</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.64 ±0.25</td>
<td>3.71 ±0.25</td>
<td>-0.25 (-0.66 to 0.17)</td>
<td>small</td>
<td>possibly</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>3.11 ±0.16</td>
<td>3.22 ±0.16</td>
<td>-0.68 (-1.10 to -0.27)</td>
<td>moderate</td>
<td>very likely</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>2.33 ±0.14</td>
<td>2.40 ±0.12</td>
<td>-0.58 (-1.00 to -0.16)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.46 ±0.10</td>
<td>1.51 ±0.10</td>
<td>-0.56 (-0.97 to -0.14)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 2m (s)</td>
<td>0.82 ±0.08</td>
<td>0.86 ±0.08</td>
<td>-0.49 (-0.91 to -0.07)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>40.01 ±7.77</td>
<td>36.75 ±6.82</td>
<td>0.41 (-0.01 to 0.83)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>185.46 ±19.62</td>
<td>169.48 ±17.46</td>
<td>0.85 (0.43 to 1.26)</td>
<td>moderate</td>
<td>very likely</td>
</tr>
<tr>
<td>SEBT (composite score)</td>
<td>94.40 ±7.75</td>
<td>94.69 ±6.74</td>
<td>-0.05 (-0.47 to 0.37)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>1026.40 ±279.30</td>
<td>1026.84 ±332.29</td>
<td>0.05 (-0.36 to 0.45)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
</tbody>
</table>

ES= effect size; CI= confidence interval; SEBT=star excursion balance test; TTS=time-to-stabilisation; ES Magnitude: <0.2 (trivial), 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large), including their inverse. Qualitative Inference: Based on the likelihood of ES > 0.20 using the following scale 25-75% (possibly), >75% likely, >85% very likely.
Table 7. Physical performance characteristics of Grade one and Grade four female netball players.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Grade one (n= 26) mean ±SD</th>
<th>Grade four (n= 8) mean ±SD</th>
<th>Mean Difference: ES (90% CI)</th>
<th>ES Magnitude</th>
<th>Qualitative Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone Hold (s)</td>
<td>93.81 ±40.00</td>
<td>52.75 ±25.78</td>
<td>1.17 (0.43 to 1.91)</td>
<td>moderate</td>
<td>very likely</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>13.34 ±0.79</td>
<td>14.85 ±1.27</td>
<td>-1.31 (-2.05 to -0.57)</td>
<td>large</td>
<td>very likely</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.64 ±0.25</td>
<td>3.91 ±0.38</td>
<td>-0.69 (-1.45 to 0.06)</td>
<td>moderate</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>3.11 ±0.16</td>
<td>3.27 ±0.21</td>
<td>-0.75 (-1.47 to -0.03)</td>
<td>moderate</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>2.33 ±0.14</td>
<td>2.42 ±0.18</td>
<td>-0.46 (-1.19 to 0.27)</td>
<td>small</td>
<td>unclear</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.46 ±0.10</td>
<td>1.49 ±0.14</td>
<td>-0.16 (-0.91 to 0.60)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>40.01 ±7.77</td>
<td>35.29 ±5.02</td>
<td>0.61 (0.01 to 1.22)</td>
<td>moderate</td>
<td>likely</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>185.46 ±19.62</td>
<td>160.13 ±14.04</td>
<td>1.37 (0.73 to 2.02)</td>
<td>large</td>
<td>most likely</td>
</tr>
<tr>
<td>SEBT (composite score)</td>
<td>94.40 ±7.75</td>
<td>92.60 ±6.37</td>
<td>0.23 (-0.42 to 0.87)</td>
<td>small</td>
<td>unclear</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>1026.40 ±279.30</td>
<td>1306.50 ±424.44</td>
<td>-0.69 (-1.41 to 0.04)</td>
<td>moderate</td>
<td>likely</td>
</tr>
</tbody>
</table>

ES= effect size; CI= confidence interval; SEBT= star excursion balance test; TTS= time-to-stabilisation; ES Magnitude: <0.2 (trivial), 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large), including their inverse. Qualitative Inference: Based on the likelihood of ES > 0.20 using the following scale 25-75% (possibly), >75% likely, >95% very likely.
Differences between playing positions

Performance measures, including raw outcomes and differences between playing positions are shown in Table 8 (Grade two) and Table 9 (Grade one). Grade two circle players jumped further than non-circle players (ES = -0.29). In contrast, grade two non-circle players demonstrated greater vertical jump heights than circle players (ES = 0.35). Additionally, grade two non-circle players were faster than circle players with small differences in 15 m (ES = -0.35), 10 m (ES = -0.33), 5 m (ES = -0.38) and 2 m (ES = -0.42) sprint times. Non-circle players demonstrated faster T-test times, with small differences found (ES = -0.55). Grade two non-circle players also performed better in both the SEBT (ES = 0.55) and the TTS (ES = -0.47). Grade two circle players were found to be taller than non-circle players, with a large difference (ES = 1.3) found in height between the positional groups. In grade one, the only clear difference was circle players ran faster than non-circle players over 20 m (ES = 0.75). All other differences in physical performance measures between playing positions were unclear.
Table 8. Physical performance characteristics of positions in Grade two.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Circle (n= 36) mean ±SD</th>
<th>Non-circle (n= 32) mean ±SD</th>
<th>Mean Difference: ES (90% CI)</th>
<th>ES Magnitude</th>
<th>Qualitative Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone Hold (s)</td>
<td>83.19 ±44.46</td>
<td>90.03 ±58.32</td>
<td>0.12 (-0.28 to 0.52)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>14.58 ±1.43</td>
<td>13.91 ±1.00</td>
<td>-0.55 (-0.95 to -0.16)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.69 ±0.30</td>
<td>3.64 ±0.19</td>
<td>-0.14 (-0.54 to 0.25)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>3.27 ±0.18</td>
<td>3.21 ±0.13</td>
<td>-0.35 (-0.75 to 0.05)</td>
<td>small</td>
<td>possibly</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>2.44 ±0.15</td>
<td>2.40 ±0.09</td>
<td>-0.33 (-0.73 to 0.06)</td>
<td>small</td>
<td>possibly</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.54 ±0.10</td>
<td>1.50 ±0.07</td>
<td>-0.38 (-0.78 to 0.02)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 2m (s)</td>
<td>0.88 ±0.70</td>
<td>0.85 ±0.07</td>
<td>-0.42 (-0.82 to -0.01)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>35.78 ±7.33</td>
<td>37.61 ±5.26</td>
<td>0.35 (-0.05 to 0.74)</td>
<td>small</td>
<td>possibly</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>170.87 ±17.53</td>
<td>165.91 ±15.39</td>
<td>-0.29 (-0.69 to 0.11)</td>
<td>small</td>
<td>possibly</td>
</tr>
<tr>
<td>SEBT (composite score)</td>
<td>91.47 ±6.34</td>
<td>95.06 ±6.63</td>
<td>0.55 (0.15 to 0.95)</td>
<td>small</td>
<td>likely</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>1125.12 ±349.51</td>
<td>976.17 ±342.79</td>
<td>-0.47 (-0.87 to -0.07)</td>
<td>small</td>
<td>likely</td>
</tr>
</tbody>
</table>

ES= effect size; CI= confidence interval; SEBT=star excursion balance test; TTS=time-to-stabilisation; ES Magnitude: <0.2 (trivial), 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large), including their inverse. Qualitative Inference: Based on the likelihood of ES > 0.20 using the following scale 25-75% (possibly), >75% likely, >85% very likely.
Table 9. Physical performance characteristics of positions in Grade one.

<table>
<thead>
<tr>
<th>Test Variable</th>
<th>Circle (n= 12) mean ±SD</th>
<th>Non-circle (n= 14) mean ±SD</th>
<th>Mean Difference: ES (90% CI)</th>
<th>ES Magnitude</th>
<th>Qualitative Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone Hold (s)</td>
<td>87.17 ±40.13</td>
<td>99.50 ±40.48</td>
<td>0.35 (-0.30 to 1.01)</td>
<td>small</td>
<td>unclear</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>13.40 ±0.74</td>
<td>13.31 ±0.85</td>
<td>-0.12 (-0.77 to 0.53)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.55 ±0.23</td>
<td>3.73 ±0.24</td>
<td>0.75 (0.09 to 1.40)</td>
<td>moderate</td>
<td>likely</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>3.10 ±0.19</td>
<td>3.12 ±0.14</td>
<td>0.08 (-0.58 to 0.74)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>2.33 ±0.17</td>
<td>2.33 ±0.11</td>
<td>-0.02 (-0.68 to 0.65)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.46 ±0.12</td>
<td>1.46 ±0.09</td>
<td>-0.05 (-0.71 to 0.61)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Sprint 2m (s)</td>
<td>0.82 ±0.09</td>
<td>0.82 ±0.08</td>
<td>-0.03 (-0.68 to 0.63)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>40.15 ±7.25</td>
<td>39.89 ±8.46</td>
<td>-0.07 (-0.72 to 0.57)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>184.67 ±15.35</td>
<td>186.14 ±23.24</td>
<td>0.03 (-0.61 to 0.68)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
<tr>
<td>SEBT (composite score)</td>
<td>95.21 ±9.32</td>
<td>93.71 ±6.40</td>
<td>-0.16 (-0.82 to 0.50)</td>
<td>small</td>
<td>unclear</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>1020.89 ±289.73</td>
<td>1031.12 ±280.96</td>
<td>0.03 (-0.62 to 0.68)</td>
<td>trivial</td>
<td>unclear</td>
</tr>
</tbody>
</table>

ES= effect size; CI= confidence interval; SEBT=star excursion balance test; TTS=time-to-stabilisation; ES Magnitude: <0.2 (trivial), 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large), including their inverse. Qualitative Inference: Based on the likelihood of ES > 0.20 using the following scale 25-75% (possibly), >75% likely, >95% very likely.
Discussion

The results of this study showed differences in the physical performance capabilities between NZ secondary school netball players in different grades. There were also differences found between playing positions within grades, providing information that could assist with position-specific coaching.

The biggest differences in physical performance measures were found when comparing grade one with grade two and four players in this study (Table 6 and Table 7, respectively). Grade one players were found to physically outperform those in lower grades in most of the physical performance measures. Grade one players were found to jump further and higher, run faster, have greater core endurance and faster change of direction speed. As teams had been pre-allocated to grades based on playing ability prior to the study, it could be expected that grade one players physically excelled in most tests to meet the physical requirements of netball at a higher level. The physical demands during a game of netball include acceleration and short sprints (forward, back and sideways), change of direction speed, side-shuffling, jumping and landing, and balance (36). Therefore, as expected, the players identified as more talented by coaches performed these physical capabilities to a higher standard.

It has been suggested that longitudinal investigations of physiological characteristics can provide important information to coaches and sports scientists through physiological profiling of athletes (141). A study evaluating height, body mass and physical performance measures of English regional academy netball players found that all measures improved across age categories from under 15 to under 19 years (141). Athletes in the under 19 age group displayed significantly faster 5 m sprint and change of direction speed times. They also jumped significantly higher than the under 15 age group (141). These findings were similar to the current study; however, groups in this study were only separated by playing level and not age. The reliability of the measures used in this study were also slightly lower than the study investigating academy netball players (Table 5). This could be due to the difference in athletic ability between academy and secondary school athletes. Additionally, the academy players were familiar with tests performed in the previous study as they were part of their normal training and monitoring routine (141), whereas the secondary school athletes in the current study were not familiar with the tests used. Both studies provide preliminary reference data to aid in athlete development with the prescription of appropriate training programs. The inclusion of age group comparisons in future studies could be important for long-term athlete development.
Previous studies in other team sports have also reported that higher ranked players physically outperform their lower ranked peers (40, 78). Manson and colleagues (2014) found that starting players were stronger in the lower body, were faster, and had a greater \( V_Q \text{max} \) compared to non-starting players in female football, providing recommendations for greater specificity in training and group selection. Similar findings have also been reported in junior elite and sub-elite rugby league players (40). Junior elite players were found to have better speed, change of direction speed, vertical jump height, and estimated maximal aerobic power, compared to sub-elite players. Additionally, differences in physical performance measures between junior volleyball players competing at the elite, semi-elite, and novice levels have also been reported, providing a performance profile and physical performance standards for this sport and age group (38). Studies investigating the physiological characteristics of rugby league and netball players at different playing levels also provided a performance profile and physical performance standards at each level of the sport (41, 126). However, comparisons were made between groups in these studies that were very different in playing ability (i.e. from professional/elite to under 19, 17 and 13 age groups) and therefore differences could be expected.

Results of this study provide a performance profile which coaches may use to assist with talent identification of youth netball players. Moderate to very large associations between relative isometric strength, vertical jump performance and sprint and change of direction speed have been found in academy netball players (140). Players considered as ‘stronger’ had the ability to produce significantly greater vertical jump height and faster sprint and change of direction times, compared to ‘weaker’ players (140). Therefore, findings suggest that maximum strength is an important aspect of physical preparation for youth netball players, and success in the sport is highly dependent on such physical characteristics (139, 140). In addition to utilising physical performance measures in talent identification, it has been reported that sport-specific skill acquisition (e.g. pattern recall, decision making, and anticipation) discriminates between expert and novice athletes (42). Performance measures could be masked if younger athletes are competing in a higher age category if their skill level is considered superior to their peers (141). A study involving junior (mean age 15.5 ±1.0 years) volleyball players, involving both male and female athletes, found no differences between selected and non-selected players for any of the physiological or anthropometric variables measured (39). It was suggested that skills were more important in identifying talented junior volleyball players (39). However, in comparison to this study, these findings were reported in different population groups, involved professional or older players and different sports, and we did not measure technical or tactical skill components of netball.
Physical demands of the seven playing positions in netball have been investigated in youth to elite level netball with differences found between positions (6, 17, 22, 35, 36, 142). Differences in physical attributes between positions in netball could be due to the court spatial constraints imposed by the rules of the game (137, 141). These constraints have been reported to influence active time during a game of netball (36) and this could affect the development of physical capabilities. Player load was found to be similar between WA and WD, and GA and GD positions, highlighting the connection between physical demands and court constraints (17, 137). Previous studies analysing positional differences in netball have investigated individual positions comparing defensive (GK, GD, WD) versus attacking players (C, WA, GA, GS) (6, 17, 35, 36) or the differences between three positions (C, GS, GK) (22). A commonality between all studies was the greatest player load and highest amount of activity found in the C position and the lowest player load and least amount of activity found in the GS position (6, 17, 22, 35, 36, 137).

When comparing physical performance and anthropometric measures in youth netball, we found differences between playing positions (Table 8 and Table 9). Non-circle players had lower straight-line sprint and change of direction times. Positions which have been found to have the greatest running and change of direction load are those with the least court constraints, therefore this could explain why the non-circle players were found to be faster at change of direction and faster over short distances. Circle players work predominantly in one third of the court only, suggesting the need to meet lower physical demands of game-play (17). Fox et al. (2013) found mid-court positions (GD, WD, C, WA, GA) performed jogging, running and sprinting more frequently. As non-circle players are moving through the court at greater speeds, they also need to be able to stop quickly and safely which could be shown by their ability to perform better during the static and dynamic balance assessments. They also need to be able to have stability when feeding and defending the ball on the edge of the shooting circle. Balance assists many movements in netball (e.g. jump and land, passing and guarding the ball) and is an important physical measure to test (113). We chose to focus on positional differences based on court area restrictions which, as shown by previous research, appear to have the most influence on physical demands. Therefore, positional groups in this study were divided into circle (GK, GS, GA, GD) and non-circle (C, WA, WD) players.

It might be expected that positions under the goal need to have a higher vertical jump for rebounds and to receive/defend high balls into the circle. However, similar to other studies (6, 17, 142), we found that non-circle players tend to have a higher vertical jump. Centre players have been found to demonstrate significantly greater jump heights compared to defending players with a trend for increased jump height compared to shooters (142). Additionally, the GS position has been found to perform far fewer jumps
than all other positions (36). It may be that, as circle players were taller than non-circle players in this study (mean difference= 6.47 cm), they rely on their height to reach or receive the ball without the need to jump. Additionally, previous findings have shown that the C position had a high vertical player load, suggesting non-circle players have a greater vertical load and thus vertical jump ability (17). However, it has also been found that the C position has the highest forward player load (17) and better performance in single leg forward hops (142), contradicting our findings which showed circle players were better at horizontal jump performance. This may be due to the difference in the level of netball players analysed in each study.

Generally, non-circle players were physically better across the board in the physical performance tests in the current study (Table 8 and Table 9). As players are still developing in this age group, it may be that the more physically able tend to take non-circle positions, and other players get ‘stuck under the goal’ due to their height. It has previously been found that height was greater in defenders compared to centres of netball players of a similar age group (142). Positional demands of netball likely explain the differences in height, where tallness could be viewed as a desirable characteristic for shooters and defence players (142). This has been suggested by Gil et al. (2007) as occasionally occurring in youth soccer. At times, heavier and bigger athletes are selected as goalkeepers, not based on their skill for this position but rather, because they are not as fit as other players in their team to play other positions. This could be a caution to coaches of this developmental age-group. If taller players do not learn how to move effectively (e.g. jump vertically instead of relying on their height), especially at this age group level, it could impact their future game development, skills and play.

**Limitations**

There were some limitations to this study. Firstly, there were no skills-based variables measured in this study. As game-specific skill qualities have been shown to be an important aspect of talent identification and team selection, it should be considered for future studies. Other qualities that may assist with talent identification include attitude, mental resilience and coordination (42). Secondly, a common discriminating variable that has been shown to determine starters and non-starters was a high VO$_2$max output (40). As we did not measure VO$_2$max we were unable to compare this measure. Therefore, field-based assessments of aerobic capacity, such as the Yo-yo Intermittent Recovery Test or Beep Test, could be included in future research in NZ secondary school netball players. Furthermore, all tests in the current study involved a range of field-based tests. Further research is needed to examine power and lower body strength characteristics of NZ netball players of this age group. Additionally, although this study involves a cross-
sectional analysis of participants from the same chronological age group, caution must be taken for the interpretation of the results as growth and maturation status were not recorded. As the maturational process is unique to each individual, this should be considered in future research involving this age group. The low sample size in some groups, particularly the small number of netball players in the Grade four group, is another limitation of this study.

Conclusion

In conclusion, the present study found physical performance and anthropometric differences between netball players of different playing grades and between playing positions. These findings add to the growing body of literature and information for talent identification and training in youth netball. Netball coaches and strength and conditioning coaches could use the findings from this study to train position-specific demands. Position-specific training is important for developing the capabilities needed for gameplay, therefore a greater awareness of this is needed when designing sport-specific skill-based training programs. It could also help to identify players for certain positions based on their physical performance skills. A program incorporating speed, change of direction ability and plyometrics should be used for non-circle positions, with the inclusion of developing horizontal force direction for circle positions. Furthermore, future studies should also consider including a skills-based test, as well as other predictors (e.g. attitude, mental toughness, physiological) that may influence talent identification and team selection in this age group.
Section 2: Effectiveness of the NetballSmart Dynamic Warm-up
Chapter 4: The Effect of the NetballSmart Dynamic Warm-up on Physical Performance in Youth Netball Players

This chapter comprises the following paper published in *Physical Therapy in Sport*.

Reference:


Overview

The purpose of this study was to investigate the efficacy of the NetballSmart Dynamic Warm-up in improving physical performance measures in youth netball players. The study used a cluster randomised controlled trial approach with a seven-week intervention in secondary school netball. A total of 81 youth netball players (Intervention group, \(n=45\); Control group, \(n=36\)) participated in the study. Performance measures included prone hold, change of direction, sprint, vertical and horizontal jump, Y-balance and time-to-stabilisation. Mixed effects models and t-tests were used to determine significant differences of pre and post measures between groups. Significant improvements in prone hold (\(\beta=20.46\) s; \(p=0.01\)) and vertical jump (\(\beta=6.73\) cm; \(p=0.01\)) were found in the intervention group compared to the control group; while horizontal jump was found to significantly decrease (\(\beta=-9.86\) cm; \(p=0.03\)) in comparison to the control group. The results of this study show the NetballSmart Dynamic Warm-up can improve some physical performance measures in youth netball players. It is recommended that coaches should consider implementing the warm-up in their netball programmes.

Introduction

Netball is a team sport that is common amongst women within the commonwealth countries (130). Despite being considered a “non-contact” sport, netball is a physically demanding game that requires a high level of fitness, strength, speed, power and agility (84, 134). It requires the performance of explosive anaerobic movements (repeated jumping, turning, sprinting, cutting, acceleration and deceleration); all while catching and passing a ball (139). Because of the demands placed on the body during a game, there is a high risk of injury to the lower body, in particular the ankle (most common) and knee (most expensive and often most severe) (84, 134). As netball is the leading women’s sport in New Zealand (NZ) with approximately 145,000 affiliated players and is the number one sport in secondary schools (92), the number of injuries is high. Therefore,
in 2016 Netball New Zealand (NNZ), in conjunction with the Accident Compensation Corporation (ACC), introduced a modified “FIFA 11+” warm-up known as the NetballSmart Dynamic Warm-up (NDW) to help reduce these injuries.

Many neuromuscular warm-up programmes have been shown to help reduce injury risk in various sports (25, 67, 76, 100, 128). A recent systematic review focused on youth concluded there was good evidence a neuromuscular warm-up was effective for reducing injury risk (27). The most investigated warm-up programme is the FIFA 11+, a full body warm-up designed in football by an international group of experts to reduce injuries in football players (9, 128). Research has demonstrated the effectiveness of this programme in both men and women, reporting 30 to 50% fewer injuries in players who performed the programme at least twice a week (28, 76, 104, 124). The majority of the exercises included in the FIFA 11+ are common exercises; however, they are not routinely used in football training programmes (28). Thus, in addition to warming the body up in preparation for training and games, adding these exercises into a warm-up programme that can become part of a football training routine should lead to strengthening of the lower body and core muscles, improvements in static, dynamic and reactive neuromuscular control, coordination, balance, agility and jump techniques (28). A key element of the programme is using correct technique and proper movement, particularly correct posture and body control and alignment (28). The NDW is based on the structure and exercises performed in the FIFA 11+, however slight modifications have been made to the programme to make it more sport-specific to netball (93). The order of the exercises has been changed and additional “high knees” and “butt kicks” exercises are included in the NDW, as well as various jump and land exercises. Like Part 2 (strength, plyometrics and balance) of the FIFA 11+, exercises in Part A (strength) and C (dynamic preparation) of the NDW have three levels of increasing difficulty. The final section of the NDW (Part D) involves netball specific preparation. In this section, instead of running and bounding across a football pitch (Part 3, FIFA 11+), the warm-up involves running (75-80% of maximum speed) and stopping at 3 m intervals, planting and cutting and a single leg plyometric exercise with single leg balance (“prop, prop and stick”). The complete warm-up is performed prior to trainings and games, however before games Part A is not included (93). For more details see the manual on the official NNZ website (https://www.netballnz.co.nz/Downloads/Assets/41254/1/NetballSmart%20Dynamic%20Warm-up:%20Booklet.pdf).

In addition to reducing injuries, neuromuscular warm-up programmes may also improve physical performance. When injury prevention programmes are regularly implemented into team trainings through warm-up it could be expected that physical performance will improve. There is existing evidence that warm-up-based injury prevention programmes
(such as the FIFA 11+) can have a positive effect on selected performance measures in some sports (football, futsal and basketball) (4, 66, 114, 154). However, several other studies have not reported improvements (72, 131, 148). Furthermore, there has been no research evaluating the effect of the NDW warm-up programme on physical performance in netball. Although the main purpose for the NDW is to prevent injuries, knowing the training effect (e.g. changes in strength and balance (3, 87, 101, 108)) caused by this warm-up programme could help in identifying the potential mechanisms behind the reduction in injury incidence as well as whether players may have additional performance benefits.

Evidence the NDW improves performance may also improve uptake and adherence to the programme if coaches are convinced there is a performance aspect to the warm-up (27). The importance of greater adherence to a neuromuscular warm-up has been reported previously as a critical point for successful implementation (129, 132). Higher adherence to the FIFA 11+ significantly improved functional balance and reduced injury risk (132). Therefore, the purpose of this study was to determine if the NDW could improve physical performance measures in youth netballers.

**Methods**

**Participants**

Initially, 137 participants were recruited to participate in this study. In total, 81 participants from 14 teams (five different schools) completed both pre- and post-testing and were included in the analysis (See Figure 3 for flow of participants). Participants were allocated to an intervention (INT: n= 45, age 13.33 ±0.48 years; height 165.41 ±6.11 cm; weight 56.97 ±10.16 kg) or control (CON: n= 36, age 13.25 ±0.50 years; height 168.76 ±4.25 cm; weight 64.50 ±10.11 kg) group. Participants were recruited through local secondary schools and a cluster randomised controlled design was used to minimise contamination bias within teams. Therefore, all players from one team were assigned to the same warm-up intervention. All participants were healthy and free from injury in the last six months and were training and competing in a secondary school netball programme at the time of data collection. All teams were involved in netball-specific training twice a week with one competitive game (duration the same for all participants). The participants had no previous resistance or neuromuscular training background. Prior to participation, all participants and guardians were fully informed of the experimental procedures before giving their informed consent and assent. This study was approved by the University Ethics Committee.
Figure 3. Flow of participants through the study

**Intervention**

The INT followed the NDW for seven weeks (3x per week), while the CON followed a ‘traditional’ netball warm-up (TNW). The NDW was delivered to the INT by a qualified trainer 2x per week before training, and 1x per week by the team coach before games. The TNW consisted of jogging, dynamic movement and sprints and was delivered by the team coach. Both programmes took approximately 15-20 minutes to complete per session.

**Testing procedures**

All testing was conducted during the early competitive phase of the netball season on-site at participating secondary schools. The tests included the Y-balance, 2-20 m straight line sprint (split sprint times), T-test (change of direction speed), jump performance (vertical and horizontal jump), prone hold, and time-to-stabilisation (TTS). All test protocols selected for this study have been used in previous research (65, 66, 79, 125). All testing was performed by the same person each time and standardised instructions and protocols were used for each test. These tests have been reported to show moderate to high within-session reliability (Intraclass correlation coefficient= 0.3-0.91) in a similar group of youth netball players (81). Participants performed a 10-minute standardised warm-up that replicated a generic netball warm-up. After warm-up and test familiarisation three recorded trials were performed at each test (with up to one-minute rest between trials). The mean of these three trials was used for analysis.
Horizontal jump

Participants started with their feet flat on the ground and toes behind a line marked perpendicular to a measuring tape (0 cm mark). They then jumped as far forward as possible landing on both feet. The participants were required to stick their landing so jump distance could be measured from the 0 cm mark to the heel of the back foot (79). If participants did not stick the two-foot landing it was considered a "non-jump" and they were required to repeat the jump until they completed three successful jumps.

Vertical jump

An AMTI portable force plate (Advanced Mechanical Technology, Inc. Watertown, MA) was used to measure vertical jump height (400 Hz sampling rate). Participants stood in the centre of the force plate, feet hip width apart and hands on their hips. They then performed a maximal countermovement jump (CMJ) keeping their lower limbs extended during the flight phase of a jump (65). A custom-made LabVIEW programme (National Instruments, 2014, Auckland, NZ) determined jump height by finding total flight time and using the following equation: jump height (cm) = 1/2 g (t/2)^2, where g = 9.81 m sec^-2 and t = time in air (85).

Time-to-stabilisation

To measure TTS, participants were first assessed for maximal vertical jump height (bilateral) using a Vertec (Swift Performance Equipment, Queensland, AUS) which was set above the centre point of an AMTI portable force plate (Advanced Mechanical Technology, Inc. Watertown, MA). Once maximum jump height was established, the Vertec was set at 50% of this value creating an individual target to control for jump height during each TTS test (65). To begin the TTS test, participants stood behind a marked line 20 cm from the centre of the force plate. Then, jumping from two feet, they performed a CMJ reaching for their individual jump height target. They were required to land on their right foot (single-leg) with their hands on their hips. The participant had to stabilise and adopt this balanced landing position as quickly as possible without any additional movement (i.e. hopping, swaying or letting the left foot touch the force plate) (65). They were required to hold this position for 10 seconds. The test was repeated if a participant fell or lost balance until three successful jumps were recorded. A custom-made LabVIEW programme (National Instruments, 2014, Auckland, NZ) was used to determine the time to stabilisation (ms) from the time of initial contact upon landing until stabilisation was within 5% of body mass (144).
**Prone hold**

Participants were required to maintain a prone hold position (elbows on the ground, hands grasped, feet approximately hip width apart, head facing towards the ground and body straight from shoulder to heels) with no arching or bowing in the lower back for as long as possible (66). The test ended if the participant could not stay in the position any longer or if they excessively arched or bowed their lower back (at the discretion of the researcher). The maximum time (s) the participant maintained a correct position was recorded. This test was performed once.

**Speed**

Split sprint times (s) (2, 5, 10, 15 and 20 m) were measured with a Radar Gun (Stalker ATS II, Applied Concepts Inc., Richardson, TX) (125). Participants started from a still, split stance position 2 m directly in front of the radar gun. They were encouraged to sprint 20 m as fast as possible for three recorded trials. All files were analysed in a custom-made LabVIEW programme (National Instruments, 2014, Auckland, NZ) to find split times at each distance.

**Change of direction**

A T-test was used to measure change of direction ability (s) (65). Cones were set up on a netball court to resemble a ‘T’ shape with timing gates (Swift Performance Equipment, Queensland, AUS) placed at the start/finish line. The T-test was performed as follows: forward sprint (5 m) through the timing gates to the top of the “T”; side-shuffle to the left (5 m) cone, then to the right cone (10 m), and left again back to the centre cone (5 m); backpedal through the timing gates.

**Balance**

A Y-balance test (modified star excursion balance test) was used to measure right single leg balance using a composite score (30, 65). A total of 7 trials was allowed for each direction. The first four trials were practice followed by three recorded trials (117). The participants’ right lower limb measurement from the most distal end of the anterior superior iliac spine to the centre of the medial malleolus were taken and recorded for the composite score (30). A Y-balance composite score was calculated by dividing the maximum reach distance in the anterior (A), posterolateral (PL) and posteromedial (PM) directions by three times the limb length (LL) of the individual participant, then multiplied by 100 \(( (A + PL + PM)/(LL \times 3)) \times 100\) (30).
Statistical analysis

Normality was tested using the Shapiro-Wilk test and by visual review of histograms. Paired t-tests were used to determine pre-post differences in all performance measures for the intervention and control groups. Mean differences and associated 95% confidence intervals and Hedges’ g effect sizes (ES) were reported. The following scale was used to interpret the magnitude of the ES: 0.2-0.59 (small), 0.6-1.19 (moderate), 1.2-1.99 (large), 2.0-3.99 (very large), >4 (extremely large) (58). Linear and generalised linear mixed effects models were developed to evaluate the effects between intervention and control groups. This approach was used to account for the cluster design using multiple sites (schools) and repeated measures (random effects). A robust standard error was applied to account for potential contamination between sites (two schools had both INT and CON groups). All models controlled for baseline measures. The threshold for statistical significance was set at p<0.05 for all analyses. Both the Statistical Package for the Social Sciences (SPSS) (IBM SPSS Statistics v. 25; IBM Corporation, Chicago, IL) and Stata (College Park, TX) were used to perform the analyses.

Results

In the intervention group there were significant improvements in prone hold (ES= 0.48, p= 0.004), vertical jump (ES= 0.53, p= 0.001), and Y-balance (ES= 0.34, p= 0.003) (Table 10). In contrast there was reduced performance in 20 m sprint (ES= 0.42, p= 0.001). The significant changes found in the control group were improvements in Y-balance (ES= 0.64, p= 0.003) and 10-15 m sprint times (ES= -0.64, p= 0.01 and ES= -0.49, p= 0.01, respectively) (Table 11).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Test Mean ±SD</th>
<th>Post Test Mean ±SD</th>
<th>Difference Mean ± 95% CI</th>
<th>ES Hedge’s g ± 95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone Hold (s)</td>
<td>82.93 ±50.65</td>
<td>105.04 ±40.73</td>
<td>22.11 (7.49 to 36.73)</td>
<td>0.48 (0.06 to 0.90)</td>
<td>0.004*</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>13.69 ±1.01</td>
<td>13.74 ±1.11</td>
<td>0.06 (-0.13 to 0.24)</td>
<td>0.05 (-0.37 to 0.46)</td>
<td>0.54</td>
</tr>
<tr>
<td>Speed Vmax</td>
<td>6.42 ±0.50</td>
<td>6.39 ±0.40</td>
<td>-0.04 (-0.13 to 0.06)</td>
<td>-0.07 (-0.48 to 0.35)</td>
<td>0.44</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.79 ±0.29</td>
<td>3.91 ±0.28</td>
<td>0.12 (0.05 to 0.19)</td>
<td>0.42 (0.01 to 0.83)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>3.27 ±0.19</td>
<td>3.25 ±0.16</td>
<td>-0.03 (-0.07 to 0.02)</td>
<td>-0.11 (-0.53 to 0.30)</td>
<td>0.21</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>2.45 ±0.14</td>
<td>2.42 ±0.13</td>
<td>-0.03 (-0.07 to 0.01)</td>
<td>-0.22 (-0.63 to 0.19)</td>
<td>0.09</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.55 ± 0.10</td>
<td>1.54 ±0.09</td>
<td>-0.01 (-0.04 to 0.02)</td>
<td>-0.10 (-0.52 to 0.31)</td>
<td>0.62</td>
</tr>
<tr>
<td>Sprint 2m (s)</td>
<td>0.89 ±0.08</td>
<td>0.90 ±0.07</td>
<td>0.02 (-0.01 to 0.04)</td>
<td>0.13 (-0.28 to 0.55)</td>
<td>0.17</td>
</tr>
<tr>
<td>Vertical Jump (cm)</td>
<td>30.60 ±8.96</td>
<td>34.74 ±6.47</td>
<td>4.13 (1.71 to 6.55)</td>
<td>0.53 (0.10 to 0.95)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>161.91 ±15.56</td>
<td>157.76 ±17.75</td>
<td>-4.21 (-8.39 to -0.03)</td>
<td>-0.25 (-0.66 to 0.16)</td>
<td>0.05</td>
</tr>
<tr>
<td>Y-Balance Test (score)</td>
<td>90.82 ±5.73</td>
<td>93.17 ±7.71</td>
<td>2.36 (0.83 to 3.89)</td>
<td>0.34 (-0.07 to 0.76)</td>
<td>0.003*</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>1426.81 ±404.64</td>
<td>1533.45 ±364.35</td>
<td>106.65 (-6.25 to 219.54)</td>
<td>0.27 (-0.14 to 0.69)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Values are mean ±SD; ES=effect size; CI=confidence interval; * Significantly different pre-post (p<0.05)
Table 11. Mean pre-post differences in the control group \(n=36\).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre Test Mean ±SD</th>
<th>Post Test Mean ±SD</th>
<th>Difference Mean + 95% CI</th>
<th>ES Hedge's g + 95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prone Hold (s)</td>
<td>90.81 ±47.82</td>
<td>88.17 ±42.77</td>
<td>-2.64 (-15.43 to 10.15)</td>
<td>-0.06 (-0.52 to 0.40)</td>
<td>0.68</td>
</tr>
<tr>
<td>T-Test (s)</td>
<td>13.61 ±1.12</td>
<td>13.64 ±0.96</td>
<td>0.03 (-0.12 to 0.17)</td>
<td>0.03 (-0.43 to 0.49)</td>
<td>0.69</td>
</tr>
<tr>
<td>Speed Vmax</td>
<td>6.72 ±0.64</td>
<td>6.73 ±0.68</td>
<td>0.01 (-0.18 to 0.19)</td>
<td>0.01 (-0.45 to 0.48)</td>
<td>0.96</td>
</tr>
<tr>
<td>Sprint 20m (s)</td>
<td>3.88 ±0.17</td>
<td>3.83 ±0.24</td>
<td>-0.05 (-0.13 to 0.03)</td>
<td>-0.24 (-0.70 to 0.23)</td>
<td>0.22</td>
</tr>
<tr>
<td>Sprint 15m (s)</td>
<td>3.31 ±0.18</td>
<td>3.22 ±0.18</td>
<td>-0.09 (-0.16 to -0.03)</td>
<td>-0.49 (-0.96 to -0.03)</td>
<td>0.01*</td>
</tr>
<tr>
<td>Sprint 10m (s)</td>
<td>2.50 ±0.14</td>
<td>2.41 ±0.14</td>
<td>-0.08 (-0.14 to -0.02)</td>
<td>-0.64 (-1.11 to -0.16)</td>
<td>0.01*</td>
</tr>
<tr>
<td>Sprint 5m (s)</td>
<td>1.60 ±0.10</td>
<td>1.55 ±0.12</td>
<td>-0.05 (-0.10 to 0.01)</td>
<td>-0.45 (-0.92 to 0.02)</td>
<td>0.06</td>
</tr>
<tr>
<td>Sprint 2m (s)</td>
<td>0.95 ±0.09</td>
<td>0.91 ±0.10</td>
<td>-0.04 (-0.09 to 0.01)</td>
<td>-0.42 (-0.88 to 0.05)</td>
<td>0.09</td>
</tr>
<tr>
<td>Vertical Jump (cm)</td>
<td>37.15 ±7.95</td>
<td>35.65 ±7.16</td>
<td>-1.49 (-3.01 to 0.02)</td>
<td>-0.20 (-0.66 to 0.27)</td>
<td>0.05</td>
</tr>
<tr>
<td>Horizontal Jump (cm)</td>
<td>173.46 ±19.65</td>
<td>174.29 ±15.83</td>
<td>0.83 (-3.08 to 4.74)</td>
<td>0.05 (-0.42 to 0.51)</td>
<td>0.67</td>
</tr>
<tr>
<td>Y-Balance Test (score)</td>
<td>90.74 ±6.07</td>
<td>94.30 ±4.97</td>
<td>3.57 (1.72 to 5.41)</td>
<td>0.63 (0.16 to 1.11)</td>
<td>0.003*</td>
</tr>
<tr>
<td>TTS (ms)</td>
<td>1392.35 ±357.30</td>
<td>1540.92 ±414.49</td>
<td>148.58 (-24.29 to 321.45)</td>
<td>0.38 (-0.09 to 0.85)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Values are mean ±SD; ES=effect size; CI=confidence interval; * Significantly different pre-post \((p<0.05)\)
Table 12. Outcomes of the mixed model comparing the effect in the intervention to the control group.

<table>
<thead>
<tr>
<th>Univariate Models</th>
<th>Variable</th>
<th>β+ 95% CI</th>
<th>Robust Std. error</th>
<th>z</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prone Hold (s)</td>
<td>20.46 (11.33 to 29.60)</td>
<td>4.66</td>
<td>4.39</td>
<td>0.001*</td>
</tr>
<tr>
<td>2</td>
<td>T-Test (s)</td>
<td>0.04 (-0.22 to 0.29)</td>
<td>0.13</td>
<td>0.28</td>
<td>0.78</td>
</tr>
<tr>
<td>3</td>
<td>Sprint 20m (s)</td>
<td>0.17 (-0.09 to 0.44)</td>
<td>0.14</td>
<td>1.26</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>Sprint 15m (s)</td>
<td>0.03 (-0.04 to 0.10)</td>
<td>0.04</td>
<td>0.72</td>
<td>0.47</td>
</tr>
<tr>
<td>5</td>
<td>Sprint 10m (s)</td>
<td>-0.01 (-0.06 to 0.03)</td>
<td>0.02</td>
<td>-0.63</td>
<td>0.53</td>
</tr>
<tr>
<td>6</td>
<td>Sprint 5m (s)</td>
<td>-0.01 (-0.05 to 0.03)</td>
<td>0.02</td>
<td>-0.61</td>
<td>0.54</td>
</tr>
<tr>
<td>7</td>
<td>Sprint 2m (s)</td>
<td>0.003 (-0.06 to 0.07)</td>
<td>0.03</td>
<td>0.09</td>
<td>0.93</td>
</tr>
<tr>
<td>8</td>
<td>Vertical Jump (cm)</td>
<td>6.73 (1.91 to 11.55)</td>
<td>2.46</td>
<td>2.74</td>
<td>0.01*</td>
</tr>
<tr>
<td>9</td>
<td>Horizontal Jump (cm)</td>
<td>-9.86 (-18.52 to -1.19)</td>
<td>4.42</td>
<td>-2.23</td>
<td>0.03*</td>
</tr>
<tr>
<td>10</td>
<td>Y-Balance Test (score)</td>
<td>-0.64 (-5.38 to 4.11)</td>
<td>2.42</td>
<td>-0.26</td>
<td>0.79</td>
</tr>
<tr>
<td>11</td>
<td>TTS (ms)</td>
<td>22.91 (-216.96 to 262.77)</td>
<td>122.38</td>
<td>0.19</td>
<td>0.85</td>
</tr>
</tbody>
</table>

* Significantly different between groups (p<0.05); Coefficient estimates the average difference in the effect between the 2 groups.

The results of the mixed effects model revealed there were some significant differences between the intervention and control groups (Table 12). Prone hold time and vertical jump height improved by an estimated 20.46 s (p= 0.001) and 6.73 cm (p= 0.01) more on average respectively in the intervention group than in the control group. Horizontal jump distance was found to decrease on average by an estimated 9.86 cm in the intervention group in comparison to the control group (p= 0.03). No other significant differences between groups were found.

Discussion

The NetballSmart Dynamic Warm-up (NDW) was developed to help prevent injury and enhance performance at all age groups and levels of netball. There have been no previous studies reporting on the efficacy of this warm-up in youth netball players. Therefore, the present study investigated the effect of the NDW on performance measures in NZ secondary school netball players. Differences were found following the warm-up intervention, suggesting that the NDW could improve some physical performance measures. These results are comparable to previous literature showing that the FIFA 11+, or similar neuromuscular warm-up programmes designed to prevent injuries, can have a positive effect on performance (4, 66, 114, 120).

The main findings of this study were the significant improvements in prone hold and vertical jump in the intervention group compared to the control group (Table 12). In accordance with this, the biggest improvements in the intervention group were also in both prone hold (ES= 0.48) and vertical jump (ES= 0.53) (Table 10). Similar
improvements in prone hold and vertical jump have been found in previous research implementing similar warm-up programmes (10, 65, 66, 114, 157). Prone hold performance was found to significantly improve in youth futsal players after performing the FIFA 11+ twice per week for four weeks (157) and in a group of youth male football players performing the FIFA 11 five days per week for six weeks (66). Core stability was also found to maintain or improve in a group of amateur male football players after performing the FIFA 11+ three times a week for nine weeks (65). The implementation of core stability exercises in injury prevention is based on the theory that dysfunction in core musculature contributes to musculoskeletal injury (64). Therefore, even though the ideal components of an injury prevention programme have not been determined (64), most multifaceted injury prevention programmes incorporate exercises that target neuromuscular control of the core through strength, endurance or balance and posture (66, 72, 120, 128, 148). According to Leetun et al. (2004), core stability is the product of motor control and muscular capacity of the lumbo-pelvic-hip complex, and muscular capacity refers to the athlete’s ability to generate or maintain force (endurance) in the lumbo-pelvic-hip complex. Improving core stability should be considered important for the prescription of all sports training programmes as sports activities are frequently performed in unstable positions (153), though there is little evidence showing how improvements in core stability can directly enhance sports performance (55, 112). In comparison, core stability has been shown to be important in injury prevention (69). Basketball and track athletes who experienced an injury over a season scored lower in core stability measures compared to those who did not get injured. Therefore, an improvement in prone hold performance (muscular endurance of the lumbo-pelvic-hip complex) may reduce the risk of injury.

Vertical jumping is a component in both the FIFA 11+ and the NDW (93, 128). The improvements we found in vertical jump have not been consistently found previously. Some studies have reported improvement in vertical jump performance after the implementation of a neuromuscular warm-up (10, 66, 154), but a number of studies have shown no significant or meaningful change (65, 72, 131, 148). Studies reporting improvements in vertical jump height have involved either football or futsal male athletes of various ages. A significant improvement of 6% was found in CMJ after performing the FIFA 11 for six weeks in youth male football players (66) and better jump height (7-10%) has also been reported in male football and futsal players of a slightly older adolescent age group after following the FIFA 11+ (114, 154). Furthermore, with the implementation of the FIFA 11+, Bizzini et al. (2013) reported significant improvements in CMJ (5.5%) in male football players (25.5 ±5.1 years). In contrast there were no improvements in CMJ in adolescent women’s football players following the FIFA 11+ or an alternate neuromuscular warm-up programme (72, 131). Due to the nature of the game, vertical
jumping is a frequent movement performed in netball (36) and this could partly explain the greater improvement (4.13 cm; 13.5%) in jump height we observed in comparison to previous football studies. Due to the game demands of netball, modifications from the FIFA 11+ to the NDW involved an increased number of vertical jumps in addition to a series of squats and lunges. This may have improved jump technique and strength in our largely untrained population. Close associations have been found between muscular strength and other various physical components, including muscular power and jump ability in the physical development of youth athletes (73). Muscular strength has also been reported to be an important factor for correct movement technique (73). Therefore, as vertical jumping plays an important role in the requisite performance of netball movements (139) an increase in vertical jump height would likely be associated with improved performance on court in netball. Additionally, an increase in lower body muscular power may also contribute to injury prevention (88). The improvement in vertical jump height after the implementation of a neuromuscular warm-up programme supports the work of Myer et al. (2005) who showed simultaneous improvements in vertical jump height and decreased varus and valgus torques at the knee, both biomechanical measures related to injury risk in sportswomen. A programme that places an emphasis on improving movement technique, such as the NDW, could alter knee biomechanics when jumping and landing resulting in performance enhancement and reduced injury risk. While the effect of the intervention was statistically significant for both vertical jump and prone hold, consideration needs to be given to the practical implications of these changes. The magnitudes of these changes were in the range of 10-20% for both measures which gives some indication that they are likely to improve performance.

Smaller, yet significant, within-group differences were found in both the intervention and control groups. The Y-balance was found to significantly improve in both groups (INT: ES= 0.34, CON: ES= 0.63). The star excursion balance test (SEBT), or simplified Y-balance test, is a common measure of balance in comparable studies (4, 10, 65, 72, 120). Balance is critical in sporting performance and reducing injury risk (16). Movements performed in sport challenge the body’s postural control system creating different balance requirements to successfully complete sporting tasks (16). A unique rule that distinguishes the sport of netball from other similar sports, such as basketball, is the footwork rule. When a player lands with the ball in their hands the first foot they land on is termed the “grounded foot” and this foot must stay on the ground or in the air until the player has released the ball. Re-grounding the grounded foot, while still in possession of the ball is a “step” which results in turn-over of the ball. Similarly, a hop, slide or drag of the grounded foot is not permitted (95). Therefore, upon receiving a pass a player must maintain balance and stability while rapidly decreasing horizontal velocity to come to a complete stop to avoid violation of the footwork rule (134). As balance is an important
physical component for successful performance in netball, normal netball training may have been enough stimulus for Y-balance to improve in both intervention and control groups. Previous studies have failed to show improvement in Y-balance after a neuromuscular warm-up in youth women’s football players (14.2 ±0.7 years) after 11 weeks, which could have been attributed to insufficient stimulus and low player attendance at training sessions (72).

Improvements in change of direction of up to 5% (T-test) (10, 114) following the FIFA 11+ have been reported previously and the recently introduced “Kids” version of the FIFA 11+ has also been shown to improve horizontal jump performance (120). This contrasts our lack of significant within-group or between-group differences in change of direction (T-test), horizontal jump and TTS. There are several possible explanations for the lack of improvements we observed. Methodological issues involving the length of the intervention and the progression of levels within the intervention possibly did not provide enough training stimulus to induce substantial or meaningful changes in some performance measures. Firstly, the length of the intervention was limited by the NZ school term schedule. Therefore, the intervention period of this study was seven weeks which is in the slightly lower range compared to previous studies where the intervention has run from 4, 6, 10, or 12 up to 30 weeks (66, 114, 131, 154, 157). A comprehensive neuromuscular training programme that included plyometric and movement, core strengthening, and balance, resistance and speed training, was found to improve measures of performance and lower extremity biomechanics (up to 92%) after six weeks (88). In comparison to the current study, the training volume was much higher with three 90-minute training sessions performed each week (88). Secondly, the study by Myer et al. (2005) reported on the importance of exercise progression (duration, volume, intensity) to achieve successful outcomes of a neuromuscular programme. The NDW intervention was prescribed at level one due to the young training age and lack of training experience of the participants, and because of the training inexperience there was no progression to level three in the seven-week intervention period. In comparison, previous studies involving the FIFA 11+ have either started at level three or progressively moved from level one to level three over the course of the intervention (10, 65). There is a strong focus on training vertical direction in the NDW, with emphasis on jump and land techniques. This could explain the significant decrease in horizontal jump performance in the intervention group. There are broad (horizontal) jumps in the NDW, however they are a level three exercise and as the intervention group only performed exercises prescribed at level one, only vertical jump variations were performed. This represents a lack of progression that would likely have occurred if a netball team followed the NDW outside of the confines of this study over an entire season or across multiple seasons. Additionally, the decrease could have been attributed to variation in testing performance.
Furthermore, as discussed in a previous study (72), there is no standard testing battery that exists between studies investigating the effect of neuromuscular warm-ups on performance. The tests selected in this study were used in earlier research investigating the FIFA 11+ and therefore used to enable comparison. However, they are not netball specific tests and more appropriate tests such as single leg hop, or a change of direction test emphasising rapid acceleration/deceleration may be better at measuring change in performance following the NDW. Additionally, some of the more difficult tests may have needed more familiarisation than the testing time constraints allowed.

Sprint (10 and 15 m) time also significantly improved in the control group but not in the intervention group, and neither group improved over the other sprint distances. There was a significant increase in 20 m sprint time in the intervention group. Similar studies involving adolescent women’s football players have also failed to show improvements in sprint performance at any distance following a neuromuscular warm-up programme (72, 131). These warm-ups, like the NDW, do not contain any specific sprint training exercises compared to the FIFA 11+ which includes a 40 m run and a sprint-specific exercise (bounding). Therefore, it is a possibility that these warm-up programmes do not contain enough training stimulus to elicit changes in sprint performance. This is in contrast to improvements of approximately 2% in 20 m sprint times found in previous FIFA 11/11+ intervention studies involving male football players (10, 66). Significant improvements in 5 and 30 m sprint times by 8.9% and 3.3%, respectively have also been found in male futsal players following a 12-week intervention of FIFA 11+ (114). As short sprints are a common movement in netball (139), exercises that help to improve sprint technique, such as bounding, could be included in the warm-up programme to help improve sprint performance.

Finally, the effect of neuromuscular warm-up programmes in previous studies has been shown to be influenced by compliance. Compliance in our study was recorded by the individual participant being present at each training session. Based on a threshold of 75% attendance, overall participant compliance to the warm-up programme was low for both intervention (56%) and control (67%) groups. These compliance rates were lower than those reported by previous studies (72-92%) (66, 148). Further exploratory analysis of our data, which only included participants who meet the 75% compliance threshold, did not reveal any additional benefit of the NDW.

**Limitations**

There were limitations to this study that should be considered when interpreting the results. Due to an unanticipated higher drop-out rate the sample size was small and could have increased the likelihood of type II error or failed to find an effect when in fact
there could have been one. Additionally, there is also a possibility of a training effect as the participants were young untrained athletes.

**Conclusion**

In conclusion, this study provides preliminary evidence that the NDW is more effective for improving some physical performance measures in youth netball players than a traditional warm-up. Players improved prone hold and vertical jump performance which are both important physical components in netball. Therefore, performing the NDW could lead to improvements in netball performance. As the programme is included in a warm-up format, it is relevant for netball coaches to consider implementing in their training programmes. This was the first study investigating the effect of the NDW on performance in youth netball and future research is recommended addressing the methodological issues raised.
Chapter 5: The Effect of the NetballSmart Dynamic Warm-up on Isokinetic Knee Strength in Youth Netball Players

This chapter has been embargoed and will only be released on the

18-October-2020
Chapter 6: Implementation of the NetballSmart Dynamic Warm-up: The Role of the Coach

This chapter has been embargoed and will only be released on the

18-October-2020
Chapter 7: Discussion and Conclusion

Netball has been identified as a physically demanding sport requiring acceleration, deceleration, cutting, changes of direction, and frequent jumping/landing (44). These physical requirements associated with this popular female sport put players at high risk of injury (52). Ligament sprains, contusions and muscles strains are the most common injury types, with the ankle the most common lower limb injury site (63). As a result, netball players need to be physically well prepared to perform successfully and limit injury risk. To achieve enhanced physical preparation there has been a recent increase in the use of neuromuscular warm-up programmes in several sports, with evidence these programmes can enhance performance and reduce injury risk (10, 76, 128). Commonly these programmes target modifiable performance factors including strength, balance, proprioception and movement quality. Specifically, neuromuscular warm-up programmes have been shown to improve several physical performance measures (10, 23, 66). Given the success of these programmes in real world settings is reliant on high adherence, evidence of performance improvements is an important factor when getting coach buy in. It is well known that coaches are a key stakeholder in the successful implementation of any injury prevention programme (151). The current evidence supporting the use of neuromuscular warm-up programmes is predominantly in males and limited to a small number of sports. A recently developed neuromuscular warm-up, the NetballSmart Dynamic Warm-up, was created by Netball NZ, in association with the ACC, to improve performance and reduce injury in netball. Given the limitations in the literature the overall purpose of this thesis was to determine if the NetballSmart Dynamic Warm-up can improve physical performance measures in youth netball players. Additionally, there was a focus on exploring the role of the coach in the implementation of the warm-up.

A series of studies were conducted to progressively address the overall purpose of this thesis and provide novel perspectives on physical performance and neuromuscular warm-up in youth netball players. To achieve the purpose, it was necessary to first determine the effect of neuromuscular warm-up programmes on physical performance. A review of literature and synthesis of previous findings (Chapter 2) highlighted that neuromuscular warm-up programmes improved some physical performance measures in team-sport athletes. However, there were limitations and gaps identified in the existing literature. Most of the studies were conducted in male football players with little evidence in female athletes and other sports. Furthermore, there was little known of performance measures (e.g. jump, speed, strength) in youth female athletes as the majority of previous studies focused on biomechanical measures of jump/land technique and/or
general movement quality changes. Given these limitations, a group of youth netball players were profiled for physical performance measures identified as important to the game demands of netball (Chapter 3). Differences in anthropometry, balance, speed, agility, lower body power and core strength between playing positions and grades were investigated. Differences in physical performance were found between grades and playing positions with grade one players demonstrating better physical capability than lower grade players. Grade one players performed better on: 1) vertical and horizontal jump, 2) speed, 3) change of direction, 4) dynamic stability, and 5) core strength. Differences in playing positions showed circle players jumped further (horizontal), and non-circle players jumped higher (vertical). Non-circle players were also faster in straight line speed and when changing direction. Additionally, circle players were found to be taller than non-circle players. This information on physical performance and anthropometric differences between youth netball players of different playing grades and playing positions could be useful for position-specific training to help develop the capabilities needed for game-play. Recommendations have been provided for position specific training. Including a programme incorporating speed, change of direction ability and plyometrics for non-circle positions and a focus on developing horizontal force production for circle positions. This information also provides preliminary evidence that may also be useful for talent identification.

To understand the effect of the NetballSmart Dynamic Warm-up on performance, a seven-week intervention programme was conducted using a cluster-randomised controlled trial design (Chapter 4). Little was known on the effect of a neuromuscular warm-up on modifiable factors in youth female netball players, therefore the same physical performance measures used in the profile study (Chapter 3) were used in the intervention study. The NetballSmart Dynamic Warm-up was shown to improve prone hold and vertical jump performance, compared to a traditional netball warm-up. This study provided preliminary evidence that some physical performance measures can be improved with the neuromuscular warm-up and resulted in the recommendation that the warm-up be included in regular netball training. It also determined initial evidence that can be provided to coaches that the warm-up can improve physical performance measures. Comparatively, a sub-group study investigating the effect of the NetballSmart Dynamic Warm-up on isokinetic strength of youth female netball players showed no effect (Chapter 5). Isokinetic dynamometry was used to assess concentric and eccentric peak torque measures of the right leg during seated knee flexion and extension at 60°/s. Even though strength is considered a modifiable factor linked to performance and injury, there were no improvements found in knee peak torque, angle of peak torque or the hamstring to quadriceps ratio following the warm-up intervention. It may be that the training stimulus (e.g. exercise type, exercise intensity, exercise frequency) of the
programme was not enough to improve maximal strength in female youth netball players. In particular, the absence of progression when delivering the warm-up may have contributed. Furthermore, the effect of neuromuscular programmes in previous studies have been shown to be influenced by compliance, however further exploratory analysis of our data did not reveal any additional benefit of higher compliance. The lack of improvement in strength measures also highlights the importance of "off-court" training. As the warm-up was not effective in improving lower limb strength, additional "off court" training may be needed if strength is to be improved.

Coaches play a key role in the implementation of neuromuscular warm-up programmes in sport. A coach determines what is delivered to players in training. Therefore, achieving the full potential of an injury prevention programme will not be possible if coaches and players do not adopt, correctly implement and maintain the regular use of such programmes. Having investigated the effect of the NetballSmart Dynamic Warm-up, further evaluation was made to consider the level of coach knowledge and their attitudes towards the warm-up and injury prevention in netball. Their experiences with the warm-up were considered to provide further insight to assist the implementation of the programme. A survey of 54 netball coaches revealed poor technique was perceived to be the most common injury risk factor in netball, and almost all coaches believed that a warm-up can reduce injuries. The ankle was correctly reported as the most common lower limb injury. The majority of coaches felt their personal coaching experience was sufficient to be able to coach the warm-up and 81% of coaches reported observing improvements in player ability after using the warm-up. Thematic analysis of the qualitative data identified three dominant themes: 1) the importance of coach education and understanding of injury prevention; 2) long-term player development; and 3) practical implementation of the NetballSmart Dynamic Warm-up. Feedback on the warm-up was encouraging and provided several recommendations for future implementation. It also highlighted that translation of injury prevention programmes from research to real-life contexts is challenging.

Limitations and future research directions

There were some limitations to this research which have been outlined below. Based on these limitations and practical outcomes that resulted from this thesis, some suggestions for future research have also been provided:

- Due to time constraints there were no measures of netball skill or movement quality included in Chapters 3-5. Measures of skill or movement quality (e.g. landing technique) could further assess changes in performance and the effect of the warm-up. Furthermore, additional netball specific tests (i.e. single leg hop,
or a change of direction test emphasising rapid acceleration/deceleration) could be included.

- The compliance for the intervention studies was relatively low (Chapters 4-5) and there were some concerns regarding how this was monitored by coaches. As compliance has been shown to influence the outcome of neuromuscular warm-ups, procedures to better report this is recommended for future research.

- There is no standard testing battery that exists between evaluating the effectiveness of neuromuscular warm-ups, making it difficult to compare results of different studies. Consideration of a standardised testing battery is needed.

- Due to the relatively small sample size (Chapters 3-5), changes in performance may not have been large enough to detect.

- The length of the intervention (seven weeks) was limited by the New Zealand school term and thus the availability of players. A longer intervention may have had more of an effect on performance measures due to a longer exposure period. This may have also allowed for the progression of exercises within the warm-up programme (Chapter 3-5).

- Due to the age of the participants in the studies (Chapter 3-5), the participants were untrained which may have created a possible learning effect in some tests. Further test familiarisation in untrained individuals may be beneficial.

- The participants of Chapters 3-5 were from the same chronological age group; however, growth and maturation status were not recorded. This information should be considered in future research involving this age group.

- Due to time constraints, there was no follow-up on coach questionnaires which could have provided further insight to answers and comments given in the survey (Chapter 6). Focus groups with coaches should be considered in the future.

- As coach feedback was the focus in Chapter 6, players were not included in the survey. Including players may provide additional feedback useful for future implementation of the programme.

**Practical applications**

- A physical profile of youth netball players can be used for training and talent identification.

- Positional differences were found for this playing group. It is recommended that a training programme for non-circle players (WD, C, WA) includes speed, change of direction ability and plyometrics, and for circle playing positions (GK, GD, GA, GS) a training programme should include horizontal force production.
• The NetballSmart Dynamic Warm-up should be included into regular netball training.
• If available, it is recommended that coaches attend a NetballSmart workshop to ensure they are up-to-date on injury and injury prevention in netball and learn how to deliver the warm-up programme.
• Confident and knowledgeable coaches will be able to correctly adjust the warm-up programme to suit their environment and overcome highlighted barriers to the programme.
• It is important that additional “off-court” training is included in the training schedules of youth netball players to help develop strength to enhance their on-court abilities.

Conclusion

This thesis provides several novel perspectives on physical performance and neuromuscular warm-up in youth netball players. To conclude, the thesis has determined a physical performance profile for youth female netball players and preliminary evidence that some physical performance measures can be improved with the NetballSmart Dynamic Warm-up. These findings should assist with promoting the programme to coaches and based on these results, it is recommended that the warm-up be implemented regularly in training. Future research addressing the limitations and building upon the ideas presented in this thesis are needed to further our understanding of warm-up and physical performance in youth female netball players.
Reference List


37. Frank BS, Register-Mihalik J, and Padua DA. High levels of coach intent to integrate a ACL injury prevention program into training does not translate to


Appendix A: Conference Abstract (Chapter 3)

The following abstract was presented at the 2017 ASCA International Conference on Applied Strength and Conditioning (ASCA):

PERFORMANCE PROFILING OF FEMALE YOUTH NETBALL PLAYERS
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INTRODUCTION: The purpose of this study was to investigate the physical performance characteristics of female youth netball players to provide a physical performance profile and determine if there are differences between level of performance (grade) and/or playing positions (circle versus non-circle) for this group. There is currently limited data on this topic and identifying a performance profile could potentially assist with selection, training, coaching and game development.

METHODS: A total of 102 youth female netball players (mean ±SD: age 13.3 ±0.50 y, height 166.95 ±5.72 cm, body mass 60.94 ±12.80 kg) participated in this study. Measurements included anthropometry (height and body mass), lower body power (vertical and horizontal jump), balance (modified star excursion balance test and time-to-stabilisation), core strength (prone hold), change of direction (T-test), and split sprint times (2, 5, 10, 15, and 20 m). T-tests were used to determine differences in all measures between players in different grades and between players in different positions.

RESULTS: Outcomes of this data showed significant differences in performance measures between playing grades. There were significant (p<0.05) differences for playing grade on jump performance, change of direction, and 5 m sprint times. Grade one players had significantly greater horizontal jump performance (mean difference: 15.98 cm & 25.34 cm, p<0.05) and significantly lower change of direction times (mean difference: -0.56 s and -1.50 s, p<0.05) than grade two and grade four players. Grade one players were also faster over 15 m compared to grade two players (mean difference: -0.11 s, p<0.05). Significant differences (p<0.05) were found in balance (mean difference: -3.59 composite score) and change of direction (mean difference: 0.68 s) between grade two circle and non-circle playing positions.

DISCUSSION: The results of this study show there were differences in the physical performance capabilities between netball players of this age group playing at different levels. There were also differences between playing positions, providing information that could assist position-specific coaching. These findings have provided general guidelines for a physical performance profile for youth netball players. The results shown in this study could be expected given the game requirements and positional demands of netball, and pre-allocated grades. Similar findings have been found in other studies specific to rugby league, football and volleyball.

PRACTICAL APPLICATIONS: Findings from this study suggest the development of horizontal lower body power, change of direction and speed is important in developing youth netball players in this age group. General guidelines of physical performance measures could also be used for talent identification and selection. Future research involving maturation status, sport-specific skills-based variables and physiological measures should be considered.
# Appendix B: The NetballSmart Dynamic Warm-up Summary

## Part A: Strengthening
### Hamstrings
- Beginner: Nordic hamstring or Single leg Romanian Dead Lift (RDL)
- Intermediate: Nordic hamstring or Single leg Romanian Dead Lift (RDL)
- Advanced: Nordihamstring Single leg Romanian Dead Lift (RDL) throw and catch ball

### Balance
1. Single leg stance - hold the ball (or imaging holding ball) Progress to moving ball around back.
2. Single leg standing, throwing ball with partner.
3. Single leg stance - face your partner. Facing partner. Hand on opposite shoulder of partner, tap each other. Keep balanced if possible or return to starting position. Continue for 30 seconds.

## Part B: Running Warm-up
### Running Straight Ahead
Run to centre of court and back. Repeat. You can vary direction of the running path as it happens in a Netball game.

### Running Hip Out
Run to first cone, stop, lift knee forwards and rotate knee out to side and put foot down. Run to next cone and repeat with other leg.

### Running Sideways and Hip Out
Butt kicks and skipping. Butt kick to first cone (kicking feet up to butt), skip to next cone, but kick to third cone. Continue for length of 15m and back.

### Running - Circling Partner
Run to first cone, side shuffle towards partner and around partner and back out to cone. Run to next cone and repeat. Continue length of 15m and back.

### Running - Shoulder Contact
Run to cone, side shuffle to the middle, jump shoulder to shoulder contact. Land in good stable body position. Continue length of 15m and back.

### Running - Quick Forwards and Backwards Sprints
Run to second cone and back to first cone. Repeat 2 cones forwards one back for length of 15m and back.
Appendix C: Coach Questionnaire

NetballSmart Dynamic Warm-up: Coaches Questionnaire

Thank you for being a part of this research study. We would like to hear your thoughts and opinions, as a coach, on the NetballSmart Dynamic Warm-up. Please be open and honest and provide as much feedback as possible. These questionnaires are not anonymous, however your privacy will be protected and all information collected will be used for research purposes only. You will not be identifiable in any published findings.

When completing the survey please click on the appropriate box of your selected answer to check the box (click again to un-check the box), or please type in the space provided.

PART A: This section asks you to provide information on your current coaching experience.

Name:
Team/s:
Please state the age group/s you currently coach:
Do you currently play netball?  ☐ Yes  ☐ No
Number of years coaching experience:
☐ < 2 years  ☐ 2-5 years  ☐ 5-10 years  ☐ > 10 years

PART B: This section asks you questions about your attitudes, perceptions and feelings towards injury/injury prevention in netball.

1. What is the most common lower body injury site in netball? (please select only one answer)
   ☐ Knee  ☐ Hip  ☐ Ankle  ☐ Thigh

2. What are common injury risk factors in netball? (please select all answers that apply)
   ☐ Inadequate warm-up
   ☐ Lack of stretching/flexibility
   ☐ Lack of fitness
   ☐ Aggression/ risk taking
   ☐ Body contact
   ☐ Poor muscle strength
   ☐ Poor technique
   ☐ Player’s genetics

3. Which of the above answers (question 2) would you rate as the most common injury risk factor in netball? Please type your answer in the space provided:

4. Do you believe male and female athletes have the same overall injury risk?
   ☐ Yes  ☐ No

5. Is inadequate warm-up an injury risk factor?  ☐ Yes  ☐ No

6. Can a warm-up reduce injuries?  ☐ Yes  ☐ No

7. Who do you believe is primarily responsible for injury prevention? (please select only one answer)
1. During the study (7 weeks) did your team complete the warm-up before every game?
   - Yes
   - No
   - Sometimes

2. Post the 7-week intervention study, do you continue to do the warm-up with your team: (please select all answers that apply)
   - Before every training?
   - Before every game?
   - Before trainings only?
   - Before games only?
   - I have not continued using the warm-up

PART D: This section will ask you about your experience, thoughts and ask for feedback on the NetballSmart Dynamic Warm-up.

How many times a week do you complete the warm-up with your team/s?
   - 1
   - 2
   - 3
   - > 3

1. Have you observed improvements of physical ability in players as a result of using the warm-up programme?
   - Yes
   - No

If yes, please indicate which physical abilities have improved: (please select all that apply)
   - Fitness
   - Speed
   - Strength
   - Movement
   - Flexibility
   - Game play
   - Other: (please provide detail in space provided)

2. What are the advantages and disadvantages of the players completing the warm-up?

**Advantages**

**Disadvantages**
3. What are the barriers to implementing the warm-up?
☐ Time  ☐ Court space  ☐ Equipment  ☐ Environment  ☐ Game play/skills
☐ Programme understanding  ☐ Other: (please provide detail in space provided)

Please comment on possible suggestions or strategies you use to overcome such barriers:

4. Is the programme applicable to all age groups?  ☐ Yes  ☐ No
5. Which age groups would you most likely use this warm-up programme with? (please select all that apply)
☐ Junior  ☐ Y7-8  ☐ Year 9-10  ☐ U17  ☐ U19  ☐ Competitive/elite
Please explain why you selected these age groups:

6. Will you use continue to use the warm-up in the future?  ☐ Yes  ☐ No

Please explain your answer:

7. Do you have any other feedback or comments regarding the NetballSmart Dynamic Warm-up?

PART E: This section will ask you about the implementation of the NetballSmart Dynamic Warm-up.

1. How did you hear about the warm-up?

2. How did you learn the warm-up?
☐ Workshop  ☐ Manual  ☐ Handouts  ☐ Videos  ☐ Another coach  ☐ Other: (please provide detail in space provided)
3. Were you given additional resources to deliver the warm-up?
☐ Yes    ☐ No
If yes, please indicate which resources: *(please select all that apply)*
☐ Website    ☐ Videos    ☐ Handouts    ☐ Coach Manual    ☐ Equipment
☐ Mentoring    ☐ Trainer instruction    ☐ Other: *(please provide detail in space provided)*

4. What resources would you like to receive to help you deliver the warm-up?
☐ Website    ☐ Videos    ☐ Handouts    ☐ Coach Manual    ☐ Equipment
☐ Mentoring    ☐ Trainer instruction    ☐ Other: *(please provide detail in space provided)*

5. Was your personal coaching experience sufficient for you to be able to coach the warm-up?
☐ Yes    ☐ No    ☐ Unsure
6. Did you feel confident delivering the warm-up?
☐ Yes    ☐ No    ☐ Sometimes    ☐ Most times

7. What assistance could further help you in the delivery of the warm-up?

8. Are there any final comments you would like to add to this questionnaire?

THANK YOU FOR COMPLETING THE QUESTIONNAIRE
If you have any questions or comments, please contact:

Dr Chris Whatman
Research Supervisor
AUT University
chris.whatman@aut.ac.nz
+64 9 921 9999 ext. 7037

Chloe McKenzie
Researcher
AUT University
chloe-mckenzie@hotmail.co.nz
+64 21 277 0673
Appendix D: Ethics Approval

AUTEC Secretariat
Auckland University of Technology
D-88, WU406 Level 4 WU Building City Campus
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics
18 January 2016

Chris Whatman
Faculty of Health and Environmental Sciences

Dear Chris

Re Ethics Application: 15/458 Effects of a modified Fifa 11+ warm-up programme on physical performance in youth netballers.

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 18 January 2019.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 18 January 2019;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 18 January 2019 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O’Connor
Executive Secretary
Auckland University of Technology Ethics Committee
Appendix E: Participant Information Sheet

Participant Information Sheet

Date Information Sheet Produced:
23 November 2015

Project Title
Effects of a modified Fifa 11+ warm-up programme on physical performance in youth netballers

An Invitation

My name is Chloe McKenzie. I am a PhD student at AUT University in Auckland and I am conducting research on netball players. I would like to invite you to be a part of my study.

You and your parents should decide together whether or not to participate. You do not in any way have to participate and may stop being a part of this study at any time. If you agree to be a part of this study, please give your consent by signing and dating the consent form.

What is the purpose of this research?

The purpose of this study is to investigate the effects of a warm-up programme on physical performance measures and how they may relate to possible injury risk in netball.

This study is being done as part of my PhD qualification and the results will be submitted to be published in a scientific journal. It may also be presented at sports science conferences.

How was I identified and why am I being invited to participate in this research?

I contacted the netball coordinators of senior high schools on the North Shore and wider Auckland area asking for their help in finding secondary school teams with players, who are currently fully participating in all trainings and games, and might be interested in participating. If you have been invited for laboratory-based testing at AUT Millennium, this is because your school is very close to AUT Millennium.

What will happen in this research?

During one of your team trainings you, along with your team, will be asked to perform a series of performance tests including:

- Balance: This test will use 8 measuring tapes shaped in a star with one middle point. Balancing on one leg you will stand in the middle and then reach as far as possible with your other foot in the same direction as the measuring tapes; you can lightly touch the floor with your toe. You then have to bring your leg back to the middle without touching the floor or letting your legs touch each other. You will then repeat this test on the other leg.
- Vertical jump: You will stand on a special platform with your hands on your hips and jump as high as you can.
- Speed: You will be asked to run at fast as you can in a straight line. The distance will be measured out by cones.
• Change of direction: You will have to run as fast as you can and change direction in a T-shape pattern. The pattern will be measured out by cones.
• Movement competency screen: You will be asked to perform a squat, lunge and jump while being videoed.

After this testing session you and your team will be asked to perform a specific warm-up, which will be instructed by either me or your coach, before each of your team trainings and games. You will do this programme for 8 weeks. After 8 weeks the same performance tests will be measured again during a team training.

If your school has been selected to be a control group in this study, you will also be asked to perform the same tests above during a team training. However, you will not be required to participate in the 8-week warm-up programme. You will continue to use your normal warm-up routine you usually perform before trainings and games. After 8 weeks you will be asked to perform the same performance tests again. At the conclusion of the study, your team/school will be offered to be educated in the warm-up programme which you can then include in your team trainings and games.

If your school is invited to take part in the laboratory testing, you will follow the same testing as above and then you will be invited to the biomechanics lab at AUT Millennium and asked to do two more tests which are outlined below:

• Movement Competency: You will be asked to perform the same types of movement (squatting, lunges and jumping) as in the movement competency screen above, but this time you will have reflective markers placed on your ankles, knees, hips and shoulders. Three-dimensional video cameras will record your movement and the markers and will help us to understand the way you move. For all jumping movements you will land on a force plate which will record how heavily you land and how high you jump.
• Leg strength: In the lab you will sit in an adjustable chair and have straps placed around your hips and thighs to keep you in place. The chair is connected to a computer and you will be asked to perform some specific movements. The computer will read your level of muscle strength of your legs.

What are the discomforts and risks?
The performance tests and warm-up programme will not be unreasonably difficult. You will experience the discomforts and risks that normally occur from participating in netball training and matches, such as running/sprinting, jumping and landing, squatting, lunging and single leg balance.

How will these discomforts and risks be alleviated?
If you appear likely to injure yourself during the performance tests or warm-up programme through incorrect movement I will correct your technique and/or stop testing. If you have a current injury or for any other reason are concerned you might injure yourself during the performance testing or warm-up programme please let me know.

You may withdraw from the study at any time, including during testing.

What are the benefits?
At the end of the research you will be given a summary of the research findings. This research will help netball coaches and players to better understand how a warm-up programme can enhance performance through decreasing injury risk. For participating in this research, including if you are in a control group, you will go into the draw to win an iPod touch. All
names collected from your consent forms will go into a draw, and one name will be drawn randomly to win the prize.

Your participation in this project will also help me to complete my PhD qualification.

**What compensation is available for injury or negligence?**

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation’s regulations.

**How will my privacy be protected?**

- All information collected will be used for research purposes only.
- Consent forms and contact details will be securely stored on the AUT campus and destroyed after a standard 6 year time period.
- Information collected in this study is not anonymous and complete confidentiality cannot be guaranteed; however, the data from the project will be coded and held confidentially in secure storage under the responsibility of the principal investigator of the study in accordance with the requirements of the New Zealand Privacy Act (1993).
- All reference to participants will be by code number only in terms of the research thesis and publications. Identification information will be stored on a separate file and computer from that containing the actual data.
- Only the investigators will have access to computerised data.

**What are the costs of participating in this research?**

There is no monetary cost to you to be involved in this research, the only cost is time. All testing sessions will take approximately 1-2 hours.

**What opportunity do I have to consider this invitation?**

- You may take one week to consider the invitation before responding.
- It is reiterated that your participation in this research is completely voluntary.
- If you require further information about the research topic please feel free to contact me (Chloe McKenzie) or project supervisor, Chris Whatman (details are at the bottom of this information sheet).

**How do I agree to participate in this research?**

If you would like to participate and are aged 16 or older all you need to do is sign the attached consent form. If you are under 16 years old your legal guardian will need to sign a consent form, while you will sign a slightly different form called an assent for m. If you do not have the form you need please call me and I will get one to you.

**Will I receive feedback on the results of this research?**

Yes, I will write up a brief overview of the results of the research and this will be given to your coach with your consent. If you would also like to receive a summary of the results you can indicate this when you complete the consent form. Please include your email address so the summary can be emailed to you.

**What do I do if I have concerns about this research?**

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Chris Whatman, chris.whatman@aut.ac.nz, +64 9 921 9999 ext. 7037.
Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O’Connor, ethics@aut.ac.nz, +64 9 921 9999 ext. 6038

**Whom do I contact for further information about this research?**

**Researcher Contact Details:**

Chloe McKenzie, School of Sport and Recreation, AUT University. Email: chloe-mckenzie@hotmail.co.nz or phone: +64 21 277 0673

**Project Supervisor Contact Details:**

*Primary Supervisor:* Dr Chris Whatman, Faculty of Health and Environmental Sciences, School of Sport and Recreation, AUT University. Email: chris.whatman@aut.ac.nz or phone: +64 9 921 9999 ext. 7037

*Additional Supervisor:* Dr Matt Brughelli, Sports Performance Research Institute New Zealand, School of Sport and Recreation, AUT University. Email: mbrughelli@aut.ac.nz or phone: +64 9 921 9999 ext. 7025

**Thank you for considering participating in this research.**

*Approved by the Auckland University of Technology Ethics Committee on 18 January 2016, AUTEC Reference number 15/458*
Appendix F: Participant Consent/Assent Forms

Parent/Guardian Consent Form

Project title: Effects of a modified Fifa 11+ warm-up programme on physical performance in youth netballers

Project Supervisor: Dr Chris Whatman and Dr Matt Brughelli
Researcher: Chloe McKenzie

☐ I have read and understood the information provided about this research project in the Information Sheet dated 23 November 2015.

☐ I have had an opportunity to ask questions and to have them answered.

☐ I understand that I may withdraw my child/children and/or myself or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

☐ I understand that any information my child/I give during this study will be confidential and my child’s/my name will not be recorded on any collected data at any time.

☐ If my child/children and/or I withdraw, I understand that all relevant information will be destroyed.

☐ I agree to my child/children taking part in this research.

☐ I agree for the results of this research to be shared with netball coaches.

☐ I wish to receive a copy of the report from the research (please tick one):
  Yes ☐ No ☐

Email address: ..............................................................................................................................................

Child/children’s name/s: .................................................................................................................................

Parent/Guardian’s signature: ............................................................................................................................

Parent/Guardian’s name: ................................................................................................................................

Parent/Guardian’s Contact Details (if appropriate): ......................................................................................
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Date:

Approved by the Auckland University of Technology Ethics Committee on 18 January 2016, AUTEC Reference number 15/458

Note: The Participant should retain a copy of this form
Assent Form

Project title: Effects of a modified Fifa 11+ warm-up programme on physical performance in youth netballers

Project Supervisor: Dr Chris Whatman and Dr Matt Brughelli

Researcher: Chloe McKenzie

☐ I have read and understood the sheet telling me what will happen in this study and why it is important.

☐ I have been able to ask questions about the study and have them answered.

☐ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.

☐ I understand that any information I give during this study will not have my name on it and my name will not be recorded on any collected data at any time.

☐ If I stop being part of the study, I understand that all information about me, including the recordings or any part of them that include me, will be destroyed.

☐ I understand information from this research will be given to my coaches.

☐ I agree to take part in this research.

Participant’s signature: ……………………………………………………………………………………………………………………………

Participant’s name: ……………………………………………………………………………………………………………………………

Participant Contact Details (if appropriate):
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…………………………………………………………………………………………

Date:

Approved by the Auckland University of Technology Ethics Committee on 18 January 2016, AUTC Reference number 15/458

Note: The Participant should retain a copy of this form