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Neuromuscular training improves movement competency and physical performance measures in 11-13 year old female netball athletes

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ABSTRACT

The purpose of this study was to examine the effects of a neuromuscular training program on movement competency and measures of physical performance in youth female netball players. It was hypothesized that significant improvements would be found in movement competency and physical performance measures following the intervention. Twenty-three junior female netball players (age, 12.17 ± 0.94 yrs; height, 1.63 ± 0.08 m; weight, 51.81 ± 8.45 kg) completed a test battery before and after a six-week training intervention. 13 of these athletes underwent six weeks of neuromuscular training, which incorporated plyometrics and resistance training. Trained athletes showed significant improvements in 20 m sprint time, 505 agility time, countermovement jump height and peak power ($p \leq 0.05$, $g > 0.8$). Additionally, trained athletes significantly improved their score in the Netball Movement Screening Tool (NMST) ($p < 0.05$, $g > -1.30$); while the athletes also demonstrated increased reach in the anterior and posteromedial directions for the right and left leg, and in the posterolateral direction for the left leg only in the Star Excursion Balance Test (SEBT) ($p < 0.05$, $g > -0.03$). Control subjects did not exhibit any significant changes during the 6-week period. Significant negative correlations were found between improved score on the NMST and decreased 5 m, 10 m and 20 m sprint time, and 505 change of direction time ($r > 0.4$, $p \leq 0.05$). Results of the study affirm the hypothesis that a six-week neuromuscular training intervention can improve performance and movement competency in youth netball players

Key words: female, strength training, resistance training, sport, injury prevention

INTRODUCTION

Neuromuscular training (NMT) programs have been shown to improve physical performance measures and reduce injury risk in youth and adolescent athletes (27, 28). Typically, NMT combines fundamental movement skill training with strength and conditioning activities such as; resistance training and plyometric training (28) to improve dynamic joint stability, enhance movement patterns and skills, improve neuromuscular control and increase strength (27). Research has shown that NMT may be particularly important for child and adolescent female athletes as they consistently show decreased levels of strength, power and performance indices, and increases in injury risk in comparison to males (12, 26, 27). One sport that may benefit from the incorporation of NMT is netball. The sport requires athletes to possess high levels of speed, agility, upper and lower body strength and power, movement competency, and anaerobic and aerobic endurance (5, 8). Netball is also commonly associated with a high incidence of lower limb injuries (11), and is one of the top five sports associated with sporting injuries in Australian children (39).

Several studies have shown that NMT programs are effective in improving physical performance measures in youth populations (10, 27, 29). Myer and colleagues (27) report that following a 6-week NMT program, 14-16 year old female athletes across three different sports significantly improved sprint time, vertical jump performance, and squat and bench press one-repetition maximums (1RMs). Similarly, another study reported that after the completion of an 8-week NMT program by grade 2 children, significant improvements were found in push-ups, curl ups, long jump, single leg hop and running performance (10). Additionally, Noyes and colleagues (29) report significant improvements in vertical jumping performance after 6 weeks of NMT undertaken by 14-17 year old female basketball players (29). The well documented improvements in performance of basketball (29) and volleyball (27) athletes suggests that similar results may be found with netball athletes of a similar age owing to similarities in physical and movement demands inherent to both sports.

Careful inspection of the scientific literature reveals that female athletes are at a higher risk of sports-related injury in comparison to males (14, 27). One possible explanation for this discrepancy is the decreased neuromuscular control females experience following maturation (15). Poor neuromuscular control can lead to poor movement patterns and predispose female athletes to an increased risk of injury (14, 23). Movement screening tools are commonly performed in order to assess movement capabilities, identify musculoskeletal and strength deficits, and predict potential injury risk in athletes (33). The Netball Movement Screening Tool (NMST) was developed specifically to replicate the movement patterns pertinent to netball in order to identify injury risk (33). The screen incorporates four components 1) the Movement Competency Screen (MCS) 2) Jump Components 3) the Star Excursion Balance Test (SEBT) and 4) the Active Straight Leg Raise (ASLR). While various movement screens were developed to assess an athlete's risk of injury (33, 38), recent research suggests that they may be largely ineffective in predicting injury (1). For example, a recent meta-analysis on movement screens suggests that the functional movement screen (FMS) may not be predictive of injury risk in active adults (9). While there may be limited utility of movement screens for prediction of injury there is evidence to suggest that movement screens such as the FMS may have a relationship to performance measures in adolescent athletes. For example, Lloyd and colleagues (23) revealed significant relationships between functional movement screen scores, reactive agility and reactive strength index (*ICCa* = 0.4-0.7) in 11-16 year old male soccer athletes. Furthermore, another study found under 16 year old rugby union players who scored lower on a movement screen had slower sprint times, scored lower on the Yo-Yo test, and jumped lower in a vertical jumping task (31), thus indicating movement competency could be related to performance in youth populations.

Research shows that movement competency can be enhanced following exposure to NMT interventions, for example; Klusemann and colleagues (18) administered a 6 week fully supervised resistance training program to junior basketball athletes, which resulted in improvements in FMS scores. Additionally, there were improvements in countermovement jump and agility performance after the 6-week training period (18). These findings suggest that when junior athletes engage in supervised training, significant improvements in movement competency and markers of sports performance capacity can occur simultaneously. Similarly, McLoad and colleagues (25) administered a 6 week NMT program to high school female basketball players, which resulted in a significant decrease in errors in the Balance Error Scoring System (BESS) as well as significant improvements in the SEBT. Improvements in balance and stability could potentially lead to improved athletic performance and reduced injury risk (25). As in basketball, balance and stability are also particularly important in netball due to the foot work rule of the game requiring athletes to decelerate, stabilize and balance when receiving the ball to avoid a step violation (40).

Therefore, the aim of the study was to determine if neuromuscular training was effective in improving physical performance indices and movement competency in female youth netball players. Based upon previous research (10, 18, 25, 27, 29), it is hypothesized that the training intervention will increase sprinting speed and agility, improve vertical jumping height and improve movement competency scores in junior netball players.

METHODS

Experimental Approach to the Problem

The present study employed a 6-week NMT program during the netball pre-season comprised of three training sessions per week completed on non-consecutive days, lasting approximately sixty minutes. The 6-week time period was chosen based on previously published literature investigating the effect of NMT in female athletes (25, 27, 29). All subjects partook in a 1-week familiarization program prior to undertaking baseline testing. Following baseline testing, subjects were randomly assigned into either an experimental or control group. After the 6-week intervention all subjects completed the post-testing sessions. The control group only participated in the baseline and post intervention testing sessions and undertook no NMT intervention during the course of the study. All subjects were instructed to continue with their normal netball training and games throughout the data collection period. All subjects had their sprinting and change of direction speed, countermovement jump and NMST performance assessed. A summary of the testing schedule is presented in Figure 1.

Insert Figure 1 about here

Subjects

A total of twenty-three junior female netball players (age, 12.17 ± 0.94 y; height, 1.63 ± 0.08 m; weight, 51.81 ± 8.45 kg) who had been competing in netball for 2 or more years and have no NMT experience were recruited to participate in the study. Age, height and weight data across subjects is presented in Table 1, with no significant differences found between control and experimental groups between the baseline or post- testing sessions ($p > 0.05$). Subjects were selected on the following criteria; currently participating in competitive netball, no prior history of lower limb injuries and no history of resistance training. Written parental consent and subject assent were provided prior to initiating the study in accordance with the Edith Cowan University Human Research Ethics Committee guidelines.

Insert Table 1 about here

All subjects completed a modified Pubertal Maturation Observational Scale (PMOS) to classify subjects into maturational categories: pre-pubertal, mid-pubertal and post-pubertal as previously used in the literature (15). All subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) prior to commencement of the study. Finally, subjects were randomly divided into either the experimental (EG; n=13) or control group (CG; n=10). Analysis of the PMOS revealed that there was no significant difference in maturational categories between the experimental and control groups ($p > 0.05$).

Testing procedures

Height was measured to the nearest 0.1 cm with the use of a stadiometer (ECOMED, New South Wales, Australia), while weight was measured to the nearest 0.1 kg on an electronic scale (Tanita Australia Inc., Kewdale, Western Australia). Both sessions also included a battery of performance and movement competency tests. Countermovement jump (CMJ), 20 m sprint, and 505 netball agility tests were used to assess the athlete's neuromuscular performance, and the NMST was used to assess the subjects's movement competency. The order of testing was constant for both testing sessions with the movement competency testing occurring first, followed by the physical performance measures. The time of testing for each subject remained consistent for both testing sessions and subjects were instructed to eat and drink water as they normally would.

Countermovement Jump Test

The subjects 's CMJ height (cm) was measured using a Vertec (Yardstick II, SWIFT, Queensland, Australia). Subjects performed a CMJ in accordance with the procedures outlined by Nuzzo and colleagues (30). Subjects were instructed to take-off from a self-selected jump stance and jump for maximum height. Subjects were given three warm-up trials, followed by three maximal effort trials with a 60 second inter-trial rest interval (32). The highest vertical jump obtained was utilized for analysis.

The vertical displacements determined in the present study were used to estimate a peak power value with the use of the Sayer et al. (36) equation:

Peak power (W) = (60.7) x (Jump Height, cm) + 45.3 x (body mass, kg) – 2,055

This equation was selected because it has previously been shown to be an accurate estimator of peak power output during vertical jumping (13, 36).

The validity of the Vertec as a tool for determining vertical jump displacement has previously been reported to be a valid tool for the assessment of anaerobic power (4, 16, 20, 30). The reliability of the assessment of vertical jump displacement using the Vertec has previously been reported to be excellent ($ICC\alpha = 0.94$) (30). Analysis of vertical jumping scores in the present study demonstrated a high degree of reliability as indicated by an $ICC\alpha = 0.89$.

Twenty-meter Sprint Test

Sprinting speed (s) was assessed using the 20 m sprint test as outlined by Netball Australia guidelines for testing netball athletes (42). Wireless infrared timing gates (Swift, Queensland) were set at distances of five, 10 and 20 m and used to record the athletes' velocity and ability to accelerate from a static position. Subjects performed three warm up sprints at 50%, 70% and 90% respectively. Subjects then performed two maximal effort sprints. All sprint trials were separated by a two minute rest period in order to ensure the subjects had adequate recovery between sprints, as recommended by the national netball protocols (42). Only the fastest 20 m sprint time was used for analysis. Five m, 10 m and 20 m sprint time and sprint velocity were recorded for analysis. Previous authors have shown high reliability of using infrared timing gates to assess sprint speed (CV = 1.00% to 1.13%) (44). Analysis of 20 m sprint scores in the present study demonstrated excellent reliability (*ICC*α= 0.97).

505 Agility Test

The 505 agility test was used to assess the subjects ability to decelerate, change direction and accelerate as outlined by Netball Australia (42). A distance of 15 m was measured with distances of 0 m and 15 m marked with masking tape and cones as directed by the national netball protocols (42). Wireless infrared timing gates (Swift, Queensland) were used to quantify the change of direction speed (s) of each athlete. Athletes were instructed to perform the change of direction element of the test with the preferred foot (42). All subjects completed two warm up trials at 50% and 70% of maximal effort. Subjects then completed three maximal effort trials with the fastest time being recorded for analysis. All 5-0-5 change of direction trials were separated by two minutes in order to ensure adequate recovery and maximize performance (42). Previous authors have reported high reliability and good within-subject variation of the 505 agility test with CV values ranging from 1.95-2.40% (41). The reliability of the 505 agility test has also previously been examined in netball players; results revealing ICCα of 0.96-0.97 for the stationary start (2). Analysis of 505 scores for the present study showed similarly high between-trial reliability (ICCα of 0.92).

Netball Movement Screening Tool

All subjects were screened with the NMST (33). This screening tool consists of four components, 1) the Movement Competency Screen (MCS) consisting of five tests: bodyweight squat, lunge and twist, bend and pull, single leg squat and push up; 2) Jump components comprised of three jump tests; CMJ, CMJ with a single leg landing and a broad jump with a single leg landing; 3) the Star Excursion Balance Test (SEBT) assessed anteriorly, posteromedially and postereolaterally; and 4) the Active Straight Leg Raise (ASLR). These tests were chosen as they reflect movement patterns relevant to netball (33). All components of the NMST were video recorded using a standard two-dimensional camera (Sony Australia, HDR-XR260VE), with the subjects observed from the frontal and sagittal planes.

Each subject completed six repetitions of each of the MCS, jump component tests and SEBT in all directions, three repetitions on each leg were completed for the ASLR as previously used in the literature (33). Screening was completed by qualified strength and conditioning coaches with extensive experience in movement screening youth athletes. Scoring occurred retrospectively, and was conducted in the same manner described by Reid and colleagues (33). Specifically, the MCS, jump components and ASLR were scored out of 33, and the SEBT was scored separately (33). Two scorers were used to assess the subjects' MCS and jump components to ensure reliability in scoring and avoid inter-observer bias; with the agreement between two scorers assessed using the weighted kappa statistic (19), whereby a score of above 0.81 was considered almost perfect, 0.61-0.80 substantial agreement, 0.41-0.60 moderate agreement and below 0.40 poor agreement (33) reliability of this movement-screening tool has previously been quantified in the literature demonstrating excellent inter-rater (ICCα =0.84) and intra-rater (ICCα = 0.96) reliability (33). Analysis of SEBT scores for the present study showed excellent between-trial reliability across all directions (ICCα ≥ 0.93).

Neuromuscular Training Program

The experimental group trained three times per week on non-consecutive days for approximately one hour, sessions were scheduled for the same time each week to ensure consistency. All familiarization and training sessions were initiated with the use of a standardized 10-minute dynamic warm-up (Table 2), followed by plyometric exercises, strength training, and finishing with static stretching. All subjects went through a comprehensive 1-week familiarization period in order to ensure familiarity with the types of resistance training and plyometric exercises that were used in the NMT (Table 3). The NMT program comprised of two, three week blocks (Table 4 and 5), in which the movement pattern remained the same but the volume and exercise complexity were increased in the second block. Exercises in the strength training sections utilized barbells, medicine balls and resistance bands. Warm-up sets of each exercise were completed starting with the lowest weight and incrementally increasing by 1.25-, 2.5-, or 5-kg until working weight was reached, with technical competency prioritized at all times. As the subjects increased weight over the 6-week period, more warm-up sets were required.

Insert Tables 2-5 about here

The OMNI Rate of Perceived Exhaustion (RPE) was used to measure RPE during the strength exercises to determine the training intensity for each session. Specifically, the load lifted was modulated in order to achieve the prescribed RPE as well as at the discretion of the strength and conditioning coach in order to insure technical competency. Subjects were explained how to use the scale to describe the level of difficulty the exercise exhibits as outlined by Robertson and colleagues (34). Prior to the session, subjects were given a RPE goal for the session (Table 6) and load was adjusted in accordance with the prescribed RPE. All training sessions were monitored by accredited strength and conditioning coaches (Australian Strength and Conditioning Association) and a certified strength and conditioning specialist (CSCS) with the coach to athlete ratio being 1:3 in order to ensure that all exercises were performed safely. If technique was deemed to be unsafe, appropriate modifications to the training load were made.

Insert Tables 6 about here

Statistical Analyses

Descriptive statistics were reported for all performance and anthropometric tests. A 2 x 2 (group x time) repeated measures ANOVA was used to compare pre- and post-test values for the control and training groups. If significant *F* values were determined, paired comparisons combined with a Holm's Sequential Bonferroni Post Hoc adjustment were performed to account for Type I errors in order to determine differences. Raw difference scores (post-baseline) were compared with the use of a one-way ANOVA. Pearson's product moment correlation coefficient was used to determine the relationship between selected variables. Statistical significance was set at $p < 0.05$. Effect sizes was calculated as Hedges *g*, because it corrects for small sample biases (7). Effect sizes were considered as trivial, <0.20; small, 0.20-0.50; medium, 0.50-0.8; large, 0.8-1.30; and very large, >1.30 (37). All effect sizes were calculated with 95% confidence intervals. Intra Class Correlation alpha (ICCα) was calculated to measure between-trial reliability across all measures (17) and were interpreted as follows; $ICC\alpha \leq 0.20$ poor, $ICC\alpha$ = 0.21 - 0.40 fair, $ICC\alpha$ = 0.41 - 0.60 moderate, $ICC\alpha$ = 0.61 - 0.80 substantial and $ICC\alpha$ = 0.81 - 1.00 almost perfect. All statistical analyses were conducted using SPSS (SPSS 23.0.0.0, SPSS Inc., Chicago, IL).

RESULTS

Twenty-metre Sprint Test

When comparing baseline versus post-intervention data, there were significant group x time interactions for 10 m and 20 m sprint ($p \leq 0.05$) performances. Conversely, there were no significant group x time interactions for 5 m sprint performance ($p > 0.05$). Based upon post-hoc analyses the experimental group demonstrated large and significant decreases in 10 m and 20 m sprint times ($p \leq 0.05$, $g > -1.2$) (Figure 2) in response to the 6-week NMT program.

Similarly, there were no significant group x time interactions for the 5 m sprint velocity ($p > 0.05$); however there were significant group x time interactions for the 10 m and 20 m sprint velocities ($p > 0.05$). When raw difference scores were examined, the experimental group demonstrated a significant and large increase in sprint velocity over 10 m and 20 m sprint times ($p > 0.05$, $g > 1.20$).

Insert Figures 2 and 3 about here

505 Agility

There was a significant group x time interaction when examining the impact of the experimental and control groups on the 505 change of direction results ($p < 0.001$). Post hoc analysis revealed that the experimental group largely and significantly reduced their 505 sprint time ($p > 0.05$, $g = -0.98$; 95%CI -1.85 to -0.10). Whilst the control group displayed an increase in their times (Figure 4).

Insert Figure 4 about here

Countermovement Jump Height

When examining the impact of the NMT program on vertical jump performance there was a significant main effect for time with both groups increasing jump height after the 6-week intervention ($p < 0.05$). There were no significant group x time effects ($p > 0.05$). However, when examining raw difference scores, the experimental group demonstrated a significant and large 0.04 m increase in their vertical jumping height following the 6-week training intervention ($p \leq 0.05$, $g = 0.84$; 95%CI -0.01 to 1.70) whilst the control group only displayed a 0.01 m increase (Figure 5).

Insert Figure 5 about here

Results of the peak power values obtained showed a significant main effect for time ($p < 0.001$) with both groups increasing peak power after the intervention. Data also revealed a significant group x time interaction, with the experimental group significantly and largely improving their peak power values following the intervention in comparison to the control group ($p < 0.05$; $g = 1.68$; 95%CI = 0.72 - 2.64).

The Netball Movement Screening Tool

Kappa scores for each individual test demonstrated substantial to almost perfect agreement between the two scorers (κ = 0.61-0.99). When comparing the effect of the NMT intervention on the NMST inclusive of the MCS, Jump Components and ASLR there was a significant group x time interaction (p < 0.001). When examining raw difference scores, the experimental group displayed a significant and very large improvement in their total NMST score (p < 0.001, $g = -2.70$; 95%CI = -3.84 - -1.57) (Figure 6).

Insert Figure 6 about here

Raw difference scores on the NMST correlated with the change scores for the 5 m (r = -0.41, $p \leq 0.05$), 10 m (r =-0.49, $p \leq 0.05$) and 20 m sprint times (r =-0.57, $p \leq 0.01$), and 505 change of direction time (r =0.428, $p \leq 0.05$). No significant correlations were found between the NMST and vertical jumping height ($p \leq 0.05$).

Results of the SEBT showed a significant group x time interaction for the anterior reach and posteromedial reach position for both the right and left leg ($p \leq 0.05$). Follow up tests revealed the experimental group anterior and posteromedial reach was significantly further then the control group for both the right and left leg ($p \leq 0.05$). Conversely, no significant group x time interaction was found for the posterolateral reach direction for the right leg ($p > 0.05$). However, a significant group x time interaction was found for the left leg ($p \leq 0.05$). Follow up tests revealed the experimental group significantly improved their reach in the posterolateral direction for their left leg only ($p \leq 0.05$) whilst the control group decreased their reach.

DISCUSSION

The main findings of the present study were that the 6-week NMT intervention significantly improved sprint and change of direction speed, CMJ height and peak, and movement competency in 11-14-year-old netball players. The control group did not show any significant improvements in any of the physical performance measures or movement competency assessments during the course of the 6-week intervention.

After the completion of the 6-week NMT program, data revealed the experimental group performed significantly better than the control group in all physical performance tests. Whilst the experimental group decreased their sprint time in response to the training, the control group became significantly slower across the 5 m, 10 m and 20 m distances as noted by the increase in sprint time and decrease in sprint velocity. Although there was no statistical difference in 5 m sprint time it should be acknowledged that the experimental group maintained their 5 m sprinting speed following the intervention. These findings are consistent with the work of Myer et al. (27) who reported adolescent female athletes improved their sprint times in the 9.1 m sprint by 0.07 s following a 6-week NMT intervention. A meta-analysis by Rumpf and colleagues (35) found plyometric training was the superior training method in improving sprint time in pre- and mid-pubertal male youth, whilst post-pubertal males benefited from a combined training method. However, following puberty sex-differences in muscular strength begin to emerge, with males experiencing natural increases in muscular power, strength and coordination that are not commonly seen in females (24). Further, the loss of neuromuscular control females experience following puberty (15) may indicate the need for an integrative NMT program inclusive of strength training and plyometric training to improve performance. Results of the current study shows the inclusion of strength training exercises to improve lower body strength and power may be an important component of improving sprinting performance in youth female athletes. The NMT program utilized in the study by Myer and colleagues (27) incorporated strength training exercises as part of the integrated NMT program (i.e. plyometrics, balance, and strength training). The strength training program incorporated back squats, bench presses, lateral pull-downs, shoulder presses, Russian hamstring curls and various isolation exercises, which were similar to the strength training exercises employed in this study. Taken collectively, the work of Myer et al. (1) and the data from the present study seem to suggest that strength training, which targets the lower body is an important component of a NMT program that is designed to improve performance in untrained female athletes.

Following the NMT program, both the experimental (+0.04 m) and control groups (+0.01 m) improved their vertical jump, however the experimental group made a much larger and significantly greater improvement. This finding is in agreement with the work of Myer et al. (27) who reported that adolescent female athletes were able to improve their vertical jump by 0.03 m in response to a 6-week NMT program. Similarly, Chappell et al. (6) found a 0.04 m improvement in vertical jump following a NMT program in college aged female athletes. Both of these studies incorporated a combination of balance, resistance and plyometric exercises. A key component of the NMT program outlined by Myer et al. (27) is that the resistance training exercises used were all executed under load. Similarly, the present study also utilized a combination of plyometric and resistance training exercises which were performed under load. Based upon the work of Myer et al. (27) and the present study it appears that NMT programs which utilize progressive overload are more effective at improving performance and movement competency as a result of systematically increasing strength levels.

It is important to note that Lesinski and colleagues (21) recently reported that youth athletes exhibit the greatest strength improvements in response to higher training intensities when movement quality and technical competency is upheld. Therefore, the inclusion of a progressive resistance training program to a NMT program may be imperative to improve jumping performance in youth athletes. The data collected in the present study reveals that the control group also displayed a small improvement in vertical jump performance (+0.01 m), although this was not statistically significant. One possible explanation for this finding is that all subjects were participating in regular netball training throughout the study. As playing netball would require some jumping performance during games and practice it is likely that this may have contributed to the improvement in vertical jump of 0.01 m over the 6-weeks in the control group. However, results of the present study indicate the inclusion of the NMT program resulted in superior vertical jump improvements when compared to netball training alone, thus suggesting that youth netball players should incorporate NMT as part of their performance programs.

When examining the 5-0-5 change of direction test, the experimental group were able to largely and significantly decrease their change of direction time following the 6-week NMT intervention, whilst the control group increased their change of direction time. These findings agree with previous research that found youth male soccer athletes were able to significantly decrease their change of direction time after completing a plyometric training program (43). The NMT program utilized in the present study incorporated a small plyometric component with a larger emphasis on resistance training, indicating the improvements in change of direction speed may have been a combination of both the plyometric and resistance training. Change of direction speed is largely effected by sprinting speed, movement efficiency and muscular strength (21). The NMT program in the current study included resistance training exercises to improve lower body strength and power with a focus on movement quality and technical efficiency. This may indicate that resistance training may play a bigger role in improving speed then plyometric training in youth female netball athletes.

After completion of the NMT program, the experimental group significantly improved their score on the NMST and had a significant increase on their dynamic balance reach distance in the three SEBT directions. These results are in accordance with the findings of Klusemann et al. (18) who found that following a resistance training program junior basketball athletes were able to improve their FMS scores. Based upon the work of Klusemann et al (18) and the data from the present study it appears that when youth athletes exhibit movement deficiencies the incorporation of a NMT program that includes resistance training appears to be a valuable tool for improving movement competency, which may directly impact performance. Lloyd and colleagues (23) investigated if a relationship exists between FMS scores and physical performance in youth male soccer athletes. Their findings showed moderate to strong (r = 0.4-0.7) correlations between the individual components of the FMS and measures of physical performance inclusive of jumping height, agility and reactive strength index. Results of the present study affirm that a strong correlation exists between movement competency, sprinting and change of direction speed in youth female netball athletes. Strong negative correlations were found between improved scores on the NMST and decreased times in the 5 m, 10 m and 20 m sprint, and 5-0-5 change of direction task. Based upon these findings it appears that a NMT program that focuses on improving movement competency may be associated with improved performance capacity in youth netball athletes. Furthermore, the NMST may be a useful test to predict physical performance capabilities in youth female netball athletes.

The NMST was created specifically to replicate the movement patterns evident in netball and as such included a specific jump component. When examining the jump scores independently the experimental group improved their score whilst the control group decreased their score. These results indicate the NMT program was effective in improving jumping and landing efficiency in youth netball athletes. This improvement in in jumping and landing quality may be due to improved motor performance due to neural adaptations from the NMT program. A meta-analysis by Behringer and colleagues (3) showed resistance training is a very effective tool for improving motor performance in youth athletes. Specifically, children made greater gains in motor skill performance in comparison to adolescents. Similarly, McLoad et al. (25) also found that following a 6-week NMT program high school female athletes were able to significantly improve their reach distance on the SEBT. The NMT program utilised by McLoad et al. (25) placed a large emphasis on strengthening exercises, whilst also incorporating plyometric, agility and balance training. The present study did not incorporate any specific balance training as part of the NMT program, indicating that the strength components and plyometric training alone were enough to improve dynamic balance without inclusion of specific balance exercises. Thereby, the inclusion of resistance training exercises to improve full body strength appear to be a very important component of NMT programs. Properly designed and implemented NMT programs that focus on improving movement efficiency, motor coordination and neuromuscular control, and thus performance measures are paramount to successful performance netball practice and competition.

PRACTICAL APPLICATIONS

Netball is a game reliant on rapid acceleration, deceleration and change of direction in combination with short bouts of sprinting, lateral movements, jumping, landing, lunging and leaping movements. The game is high intensity in nature and requires athletes to possess amongst other physical qualities, lower body power, sprinting and change of direction speed, strength and technical competency. Completion of an integrative NMT program is important for their athletic development to prepare them for the high-intensity nature of the game and to improve performance in netball practice and competition. The current study suggests that acute beneficial adaptations (6 weeks) in CMJ height and peak power output during jumping, sprinting performance, change of direction speed, and movement efficiency in youth female netball athletes were elicited through a NMT program that used progressive resistance training in combination with plyometric training three times per week. We suggest compliance to a NMT program inclusive of both resistance and plyometric training to elicit greater performance improvements in youth netball athletes. Due to the decrease in neuromuscular control in female athletes following puberty and heightened injury risk, the present training study may also decrease potential for injury risk in netball by improving neuromuscular control, motor coordination and dynamic joint stability as indicated by the improvements in the movement screen performed in the present study. If similar NMT programs were included during the pre-season and off-season training periods youth netball athletes may achieve a heightened level of performance during competition. Given the short-term nature of the present study, practitioners are advised that in order to facilitate long term adaptation, systematic changes in training prescription are required ideally as part of a long-term athletic development plan (22).

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FIGURES

Figure 1: Data Collection Timeline

Figure 2: Comparison of Performance Change Scores in Sprint Performance between the Experimental and Control Conditions.

Note: * = significant difference between groups ($p<0.02$)

Figure 3: Effect Size Comparison between the Experimental and Control Group Raw Difference Scores (Post – Pre) for Selected Sprint Variables.

Figure 4: Comparison of 505 Agility Change Scores between the Experimental and Control Conditions

Note: * = significant difference between groups ($p<0.05$)

Figure 5: Comparison of Performance Change Scores in Vertical Jump Performance between the Experimental and Control Conditions.

Note: * = significant difference between groups ($p<0.05$)

Figure 6: Comparison of Performance Change Scores in NMST Performance between the Experimental and Control Conditions.

Note: * = significant difference between groups ($p<0.05$)

TABLES

Table 1: Subject Characteristics

Note: * = significant difference between groups ($p<0.05$)

Table 2: Dynamic Warm Up

Table 3: 1-Week Familiarization Program

Note: * if athletes could not perform a traditional push-up they were allowed to use a modified technique with knees on ground

Table 4: NMT Training Block 1 (Weeks 1-3)

Note: Plyometric training was done prior to each of the strength training sessions.

Table 5: NMT Training Block 2 (Weeks 3-6)

Note: Plyometric training was done prior to each of the strength training sessions. *if athletes could not perform a chin-up resistance bands were used to assist them. In this case the resistance bands were modified to reduce reliance on the band across the training period.

Table 6: RPE Session Goal Based on OMNI Rate of Perceived Exhaustion Scale

Table 7: NMST individual movement scores during pre- and post-intervention testing for experimental and control conditions

Table 8: SEBT Results during pre- and post- intervention testing for experimental and control conditions