Strength and Conditioning for Netball: A Needs Analysis and Training Recommendations

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ABSTRACT

THERE IS A LACK OF STRENGTH AND CONDITIONING RESEARCH INTO THE DEMANDS AND THE SPECIFIC AREAS OF DEVELOPMENT REQUIRED TO OPTIMIZE PERFORMANCE AND REDUCE THE RISK OF COMMON INJURIES IN FEMALE NETBALL ATHLETES. NETBALL IS PREDOMINANTLY ANAEROBIC, CHARACTERIZED BY FREQUENT HIGH-INTENSITY MOVEMENTS THAT REQUIRE HIGH LEVELS OF STRENGTH, POWER, AND LOWER LIMB CONTROL. HOWEVER, THERE IS LIMITED RESEARCH IN THE PREPARATION OF FEMALE NETBALL PLAYERS FOR TRAINING AND COMPETITION. IN THIS REVIEW, WE PRESENT THE PHYSIOLOGICAL DEMANDS OF TRAINING AND COMPETITION, COMMON CAUSES OF INJURY, AND STRENGTH AND CONDITIONING TRAINING RECOMMENDATIONS TO ENHANCE PERFORMANCE AND REDUCE THE LIKELIHOOD OF INJURY IN FEMALE NETBALL PLAYERS.

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INTRODUCTION

Netball is a team sport that has one of the largest participation rates within the British commonwealth, played on a 30.5 × 15.25 m court divided into thirds each measuring 10.17 m. Netball consists of four 15-minute quarters separated by 5 minutes of rest at half-time and 3 minutes between other quarters. Each team consists of 7 players on the court at one time, with each area of the court accessible to each player determined by position. The 7 different positions comprise center court (center [C], wing attack [WA], wing defense [WD]), shooters (goal attack [GA], goal shooter [GS]), and defenders (goal keeper [GK], goal defense [GD]). Thus, players are constantly involved in offensive and defensive maneuvers, affecting the technical, tactical, and physical demands of each position. To perform at high levels, players must be able to cope with the physical demands of the game.

During netball matches, published data demonstrate that a high level of aerobic conditioning is required for the sport with average heart rates (HRs) reported to be between 75 and 85% of the maximum HR (MHR) during match play (17,85). However, although the performance within netball is primarily associated with a player's aerobic endurance (because of the duration of the game, 60 minutes), the performance, crucial moments, and the outcome of a netball match is dependent on the performance of decisive anaerobic activities (35,37). Netball matches show players change the intensity of the activity every ~6 seconds during the 60 minutes (26), with anaerobic variables such as the amount of running and sprinting bouts to be 25–202 and 5–81 times (26,35), respectively. This has shown to equate to running distances totaling between 143–1,758 and 69–555 m as sprinting (26). These decisive anaerobic components associated with netball (sprinting, turning, jumping, changing pace, cutting, and accelerating and decelerating the body) are forceful and explosive and require near-maximum levels of muscular strength and power production (18,67). Thus, it can be determined that physical qualities play an important role in the requisite performance of netball techniques.

KEY WORDS:
athletic qualities; netball; power; strength; testing; training

This article aims to analyze the physiological and injury considerations of netball and provide practical recommendations for testing and developing strength and conditioning programs.

TIME-MOTION ANALYSIS

A high level of conditioning is important in netball given its intermittent nature, where players perform frequent high-intensity bouts of activity, interspersed by periods of low-intensity recovery. In game play, 6 specific movements have been identified, including stationary, walking, jogging, shuffling, running, and sprinting (35), with 35–52% of active game time spent walking across all positions (35).

Because of netball rules, players are required to distribute within 3 seconds of receiving the ball. Thus, short duration, high frequency of activity highlights the intermittent nature of netball. Fox et al. (35) found the average duration of work to be <6 seconds across all positions, with nearly all undertaken within 1–2 seconds. In netball, players are allowed one additional step before either stopping or passing a ball to a teammate; so, players may already preempt their next movement or play before landing or transitioning to another high-intensity activity. Center court players are shown to perform more frequent multidirectional movements than GK and GS, changing activity every 2.8 seconds with a work:rest ratio of 1:2 (26). These findings are expected because of the positional demands placed on GKs and GSs as they are restricted to the shooting circle only (35).

Analysis of English Superleague match play reveals that C players cover up to 8 km, whereas GK and GS cover on average 4.2 km (26). Additionally, GSs players cover more distance sprinting than GKs (370 ± 233 versus 69 ± 54 m), whereas GKs accumulate more distance shuffling than GSs (2,037 ± 233 versus 1,430 ± 272 m). However, no analysis of WA, WD, GD, or GA positional demands was made. Given GD marks GA and GK marks GS, one could speculate that the physiological demands placed on these players would be fairly matched. This notion is supported by findings by Chandler et al. (17) who found WA and WD players to exhibit similar player load (load per minute), likely because of similar court restrictions irrespective of their attacking and defensive duties, respectively. Fox et al. (35) revealed that GD and WD perform the highest average duration for shuffling, possibly because of defensive responsibilities as sprinting, passing, and catching are associated with attacking play. GD and WA are shown to be the second most active positions on court, after C players (32). These findings are likely because of the short high-intensity nature of the roles rather than the constant "running" nature of the C. Although video footage of player movement in these roles has been established, further research is required to directly investigate the physiological demands of these positions.

In support of time-motion analyses, research indicates that higher standard players accumulate greater load per minute (AU) in each position in all periods of the match (9.96 ± 2.50 versus 6.88 ± 1.88 AU) than lower standard players (22). Moreover, lower standard C players have demonstrated lower (−7.7 ± 10.8%) load per minute in the second half compared with the first half, whereas the difference between first and second halves' load per minute was unclear in higher standard players. These findings suggest that netball players progressing from lower to higher standard of competition need to develop the physical qualities required to enable them to perform at the required intensity. This substantiates previous research (95) that physical characteristics develop across age categories in academy netball players. Furthermore, accelerometer data have shown centers to exhibit significantly greater load per minute than all other positions in collegiate netball match play (17,32). Specifically, C players had higher forward, vertical, and sideward load per minute than all other positions, likely because of the least positional restrictions. Fish and Greig (32) also found that GSs were exposed to the lowest load per minute, which was significantly lower than all other positions, except GKs. Similarly, Chandler et al. (17) found that GKs and GSs exhibited lower load per minute than all other positions. These findings suggest that the physical demands of netball are position specific because of court restrictions; however, it is essential that these athletes have highly developed aerobic energy systems to cope with the total distance covered, recover from high-intensity bouts, and the duration of the game.

PHYSIOLOGICAL RESPONSES TO TRAINING AND COMPETITION

To date, there is scarce information relating to the physical demands on netball match play and training-related activities (17,85). Steele (85) summarized the physiological responses to netball training and match play, revealing 50% of match play was performed at an average of 75–85% of MHR, whereas 43% of training time was spent <75% of MHR. This reveals that typical netball training activities do not meet the physical demands of competition. However, no comparisons of training modality were made, making it difficult to identify the most and least demanding training activities.

Research by Chandler et al. (17) investigated the physical demands during match play and training sessions classified as skills, game based, traditional conditioning, or repeated high-intensity effort training in collegiate netball players. Findings revealed that load per minute was significantly lower in match play (6.1 AU) and skills training (6.0 AU) than all other modes of training (9.0–18.5 AU). Additionally, mean HR of skills training was significantly lower (144 beats per minute) than match play (174 beats per minute) and all other modes of training (170–179 beats per minute), whereas peak HR for skills training (186 beats per minute) and traditional conditioning (185 beats per minute) was like match play (193 beats per minute). These results indicate that traditional conditioning may best replicate the HRs observed during match play, but skills training may best replicate the movement demands of match play, in addition to incorporating technical aspects of play. Furthermore, greater accelerations were found in all planes of movement in game-based conditioning. These findings are likely because of this mode of training using reduced player numbers, larger playing area, and rule changes. Similar physiological responses have been observed during small-sided games (SSGs) in team sport practices (51). Another important finding was no difference in rating of perceived exertion between match play and training modes, indicating a mismatch in the physical and perceptual demands of netball training and competition. Therefore, more research is warranted into the perceived exertion of netball match play and common training sessions to effectively quantify training and competition loads. Taken together, these findings indicate that an integration of training modalities may be necessary to prepare netball players for the high-intensity demands of competition.

INJURY RISKS

Landing is a fundamental skill of many movements performed during netball. Given that running with ball in hand is a rule violation, players often perform leaps and bounds to evade opposition to receive and distribute a pass. Therefore, the choice of landing is dependent on the situation and needs of the player. These explosive jumps combined with abrupt landing decelerations impose hazardously high ground reaction forces (GRFs) on the lower body (83). These GRFs coupled with incorrect landing technique have been suggested as a primary cause of lower-body injuries among female netball players (83,85,87,88). Previous research has found the ankle to be the site most commonly injured in netball (84%), with 67% determined as lateral ligament sprains (52). Furthermore, research demonstrates that anterior cruciate ligament (ACL) rupture is the most common knee injury in netball. The fact that females tend to demonstrate greater knee valgus angles and moments, decreased knee flexion, and higher GRFs during landing and cutting may in part explain this increase in ACL injury risk (33,48,78). However, appropriate lower limb control and strength training have been shown to reduce knee valgus angles and moments (44,69) and GRFs and increase hamstring strength while also improving performance (46,47). For example, Herrington (44) found that performing 3 × 15-minute sessions per week of jump training for 4 weeks reduced knee valgus angle by 9.8°–12.3° in female basketball players while increasing crossover hop distance jumped by 73.6%. Jump training focused on appropriate landing strategies while progressing from bilateral to unilateral exercises in multiple planes. Correct landing mechanics and strategies should be emphasized in closed-skill practices before progression to open-skill jump training activities to increase transference to netball (45). Stuelcken et al. (88) investigated 16 ACL injuries sustained by elite-level netball players, identifying 2 common scenarios for ACL injury to occur: (a) players received a perturbation in the air when jumping to receive or intercept a pass, leading to an unbalanced landing, and (b) rotation and lateral flexion of the trunk relative to foot alignment, before jump landing was completed. Additionally, 13/16 cases landed with a split- or single-leg technique, apparent knee valgus collapse was identified in 8/12 cases, and the positions in which most injuries occurred were C and WA (13/16 cases). These findings support those by Fox et al. (36) in that C, WA, and WD players perform more jump landings from leaping and hopping and are involved in multidirectional movements during play. Therefore, when training C, WA, and WD players, a wide range of bilateral and unilateral landing scenarios should be employed to ensure game specificity is met.

Previous research (50,59) has shown that netball players perform jump landing in forward, vertical, and lateral directions, with the majority performed unilaterally. Similarly, Fox et al. (34) found unilateral landings to occur frequently in elite netball, concluding that emphasis should be placed on performing unilateral landings correctly, in a wide range of landing scenarios to ensure game specificity is met. Research has shown attacking players to frequently (66% of the time) perform jumps with turns while in flight, in addition to performing a subsequent jump upon landing 32% of the time (62). Therefore, it is likely that different landings from different jumps performed are specific to the positional demands and the in-game scenario.

Several studies have revealed that players produced landing forces of 2.4–5.7 times body weight (BW) for vertical GRF and 2.0–4.6 times BW for horizontal GRF when landing or coming to an abrupt stop during laboratory experiments (67,83,84) with the majority being unilateral landings and GRFs occurring within the first 30% of the landing phase, indicating the rate of loading to be an important factor in the risk of ACL injury.

ANAEROBIC QUALITIES: STRENGTH, POWER, SPEED, AND AGILITY

Sprinting and change of direction (COD) require high levels of relative strength to overcome inertia and control BW through acceleration and deceleration, respectively (81,82). Research has found GRFs of 1.65–4.22 times body mass (BM) during COD in volleyball athletes (6). Therefore, greater levels of maximum strength may improve an athlete's ability to hold static and dynamic positions, such as sprinting and COD (64,81,82), thus providing a greater acceleration, acceptance of higher eccentric forces, and greater frequency of repeated high-intensity exercise (24,25).

The normative research data for netball players range from 0.34 to 0.41 m and 0.35 to 0.46 m for squat jump (SJ) and countermovement jump (CMJ) height, respectively (93,95). These scores are greater than female basketball data (0.25–0.48 m) (41,61), illustrating superior strength and power in female netball players. It has been reported that a strength discrepancy of ≥10–15% between limbs is considered a significant muscle strength asymmetry (MSA) (57), but it is inconclusive whether such imbalances affect athletic performance or a greater risk of injury. Isometric asymmetrical differences have been observed between dominant and nondominant limbs for peak force and time-specific force values (1–3,73), with researchers reporting larger MSA in weaker female athletes compared with stronger athletes (3,73). Moreover, larger MSAs have been associated with lower jump heights and lower peak power in loaded and unloaded jumps (1). Therefore, strength training recommendations to reduce MSA are found to be equally proficient at improving jumping, landing, and COD on both limbs, thus highlighting the importance of maximum strength in netball players because of the high-intensity COD, jump landing, and injury risks associated with the sport. MSA has typically been assessed via isokinetic dynamometry, isometric midthigh pull, vertical jumping, and horizontal hop tasks (28,49,55,63,70), with the magnitude of MSA likely task dependent. Furthermore, Hewit et al. (49,50) reported that using jump tests only performed in one direction may not represent an accurate player profile, as jump performance in one direction may not necessarily predict jump performance in another. Therefore, the inclusion of a unilateral measure of horizontal hop performance, such as a single hop for distance, is recommended.

When compared with Australian under 17 netball players (93,95), United Kingdom regional academy under 17 players had faster 5-m (1.25 ± 0.09 versus 1.15 ± 0.07 seconds) and 10-m sprint times (2.07 ± 0.10 versus 1.98 ± 0.08 seconds). These findings are similar to those found between under 19 age groups in the same athlete cohorts (5 m: 1.24 ± 0.08 versus 1.10 ± 0.07 seconds; 10 m: 2.06 ± 0.09 versus 1.94 ± 0.08 seconds) (93,95). However, these differences do not appear to be the product of superior strength levels. Data from Australian netball scholarship players reveals similar lower limb maximum strength data, in terms of both absolute and relative strength performances (absolute: 71.4 ± 12.6 versus 71.5 ± 7.8 kg; relative: 1.0 ± 0.2 versus 1.1 ± 0.1 kg) in a 3 repetition maximum (RM) back squat (93). These findings suggest that maximal strength and speed development should be emphasized as part of a periodized training program, ensuring appropriate development of each component dependent on the athletes' specific needs.

Professional netball players have been reported to execute a change in activity pattern on average every 6 seconds (26,35). However, positional and court restrictions prevent players from achieving a maximal velocity. Therefore, the ability to change velocity or direction to evade a defender or when reacting to an attacker plays an important role in netball performance (35,37). Accordingly, agility and COD tests are commonly included in netball physical performance testing batteries to evaluate the physical attributes which underpin these performance qualities. The 505 is a commonly used test to assess COD in team sport athletes (5,72,81,82). Previous studies have reported 505 time to range from 2.43 to 2.59 seconds in netball players (5,95). These values are similar to those reported in female collegiate basketball players (2.43–3.03 seconds) (81,82), highlighting similar COD abilities between the 2 sports. In contrast, Farrow et al. (31) found that netball players were able to demonstrate faster time to completion during a reactive agility test than previously reported in female basketball players (3.57–3.83 versus 4.47–5.34 seconds) (81). Farrow et al. (31) also found that moderately and highly skilled netball players were able to perform agility testing significantly faster than less skilled players. This finding is consistent with findings of past studies (38,77,99), revealing agility testing can distinguish between higher and lower level players but COD testing cannot.

AEROBIC CAPACITY

Previous research suggests that aerobic and anaerobic performances are of high importance in team sport athletes, with higher level players achieving greater distances in the Yo-Yo intermittent recovery test level 2 compared with lower level players (4). Research using the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) found that national team players from Australia achieve greater distances than under 17 and under 19 players (1,492 versus 1,013 and 1,320 m, respectively) (93). The Yo-Yo IR1 determines a player's ability to recover from and repeatedly perform high-intensity exercise (60). Research shows that peak speed reached during the Yo-Yo IR1 is related (r = 0.75–0.83) to $\dot{V}O_2$max-related variables in soccer players (16). However, the Yo-Yo IR1 test has limitations in testing and prescribing training in intermittent team sport athletes. Although the Yo-Yo IR is a popular test to administer, final velocity achieved during the Yo-Yo IR tests does not allow for individualized high-intensity training (HIT) (10,30). In contrast, final velocity (V_{IFT}) achieved during the 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$) has been shown to be more accurate (coefficient of variation = 3%) for individualizing HIT in team sport athletes than when using continuously determined running speeds (10). Recent evidence suggests that the $30\text{-}15_{IFT}$ demonstrates high validity and reliability in athletes competing in handball, basketball, soccer, ice hockey, and rugby league (9,42,75). Thus, the $30\text{-}15_{IFT}$ is highly specific, not to netball but, to the HIT sessions commonly performed in intermittent team sports (11). Regional academy netball players demonstrate V_{IFT} values ranging from 16.40 to 18.14 km/h during the $30\text{-}15_{IFT}$ (95). The majority of these scores are similar to those reported in male and female handball, male soccer, and rugby league (11,75), illustrating that high levels of cardiorespiratory fitness are required for netball competition, despite the positional restrictions placed upon players. In general, it is

Table 1
Battery of field- and gym-based tests suitable for netball players

Skinfold assessment	Identifies body fat percentage. This assessment is to enable the regulation of nonfunctional mass, which would impede performance by reducing propulsion and exercise economy by the muscular system having to continuously overcome the body's inertia.
SJ	Measure of lower-body explosive performance. Allows the calculation of SSC performance using different equations including RSI, EUR, PSA. If coaches have access to a force platform, then the DSI can be calculated by the formula: SJ peak force/isometric midthigh pull peak force.
Countermovement jump	Measure of lower-body explosive performance
Drop jump (0.3 m)	Measure of an athlete's SSC ability from dividing jump height by ground contact time to determine RSI. Additionally, if equipment is not available to measure ground contact time, researchers and practitioners can simply monitor jump height as the performance measure.
Single hop	Measure of MSA. Using jump tests only performed in one direction may not represent an accurate player profile, as jump performance in one direction may not necessarily predict jump performance in another (49,50). Additionally, horizontal hop tests are commonly used to assess both performance and injury risk (63,68).
5- and 10-m sprint	Evaluation of acceleration and short-sprint performance. Sprint distances are indicative of mean sprint durations during match play (26,34), given netball players rarely sprint distances to achieve a maximum velocity.
Modified 505 CODS	Assesses an athlete's ability to change direction. The modified 505 is recommended because of the inclusion of a single change in direction. Furthermore, as 505 time is highly influenced by linear sprint speed, a more isolated measure of CODS can be calculated via the COD deficit formula: mean modified 505 time − mean 10-m sprint time (71).
Isometric midthigh pull	Measure of isometric lower-body strength, which is strongly correlated with jumping (59), sprinting (94), and changing direction (81). Performance of this test requires the use of a force platform to determine an athlete's isometric force-time characteristics.
1RM back squat	Measure of maximum muscular strength, which as described is significantly related to jumping, sprinting, and changing direction. This should only be included once an athletes' technique is of sufficient standard.
$30\text{-}15_{IFT}$	Measure of aerobic and anaerobic capacity, intereffort recovery ability, anaerobic speed reserve, and COD ability. The $30\text{-}15_{IFT}$ allows prescription of individual HIT based on V_{IFT} achieved during the test to achieve the desired physiological responses and adaptations. The velocity attained during the last completed stage is noted as the player's V_{IFT}

$30\text{-}15_{IFT}$ = 30-15 intermittent fitness test; CODS = change of direction speed; EUR = eccentric utilization ratio; HIT = high-intensity training; MSA = muscle strength asymmetry; PSA = prestretch augmentation; RM = repetition maximum; RSI = reactive strength index; SSC = stretch-shorten cycle; V_{IFT} = maximal intermittent running velocity.

suggested that the aerobic fitness levels of female netball players should be developed to the highest levels because of the intermittent nature of the sport. Research in rugby union has shown aerobic performance to strongly relate (r = 0.75) to distance covered during match play in elite rugby union players (92). Furthermore, players who show greater levels of lower-body strength and high-intensity running ability (Yo-Yo IR1) demonstrate lesser change

Table 2 Example strength endurance program							
Session 1				Session 2			
Exercise	Sets	Reps	Intensity (% 1RM)	Exercise	Sets	Reps	Intensity (% 1RM)
Back squat	2–3	10–12	70–80	Front squat	2–3	10–12	70–80
Split squat	2–3	10–12	70–80	RFESS	2–3	10–12	70–80
RDL	2–3	10–12	70–80	Deadlift	2–3	10–12	70–80
Press-ups	2–3	10–12	BW	Chin-ups	2–3	10–12	BW
Drop landings	2–3	4–6	0.30 m box	Nordic curls	3	3	BW

BW = body weight; RDL = Romanian deadlift; Reps = repetitions; RFESS = rear foot elevated split squat; RM = repetition maximum.

in creatine kinase levels after match play, despite performing more repeated high-intensity efforts than players of lower fitness and strength levels on Yo-Yo IR1 performance (56). Therefore, a higher level of aerobic conditioning is likely to enable the netballer to practice and compete longer at higher intensities.

FITNESS TESTING BATTERY

Based on the needs analysis conducted above, a suggested battery of tests have been identified to assist researchers and practitioners in determining a netball player's level of development for each of these physical qualities (Table 1). This information plays an important role in the evaluation of training effects and can provide a rationale with which to individualize strength training programs to improve specific physical qualities required for successful netball performance.

PRACTICAL APPLICATIONS: STRENGTH TRAINING RECOMMENDATIONS

Several studies have documented the importance of relative maximum strength within athletic performance (91). This may be explained by the fact that peak GRFs and impulse are strong determinants of netball-specific actions, such as jumping, sprinting, and COD (27,54,80,81,96–98). Greater lower limb relative strength is required to overcome the inertia of BM and improves an individual's ability to accelerate and decelerate during actions, such as jumping, sprinting, and COD, thereby reducing injury risk and performance decrement (24,25,86).

McBride et al. (64) demonstrated that collegiate football players with a high relative strength (≥2.1 kg/kg) in the back squat had significantly faster sprint times (10 and 40 yd) compared with players with a lower relative strength (<1.9 kg/kg). These results are likely attributed to the fact that high levels of strength and acceleration are required to overcome the inertia of the BM. Similarly, Hori et al. (53) found that athletes with a greater 1RM hang power clean performance (top 50%) demonstrated significantly superior 20-m sprint and CMJ performances than those in the bottom 50%.

The strong relationships between relative maximum strength and netball-specific performance measures might be explained by the fact that athletes who exhibit greater strength levels are able to produce higher propulsive GRFs and impulse during actions, such as jumping, sprinting, and changing direction (27,54,80,81,96–98). Also, training-

Table 3 Example strength program							
Session 1				Session 2			
Exercise	Sets	Reps	Intensity (% 1RM)	Exercise	Sets	Reps	Intensity (% 1RM)
Back squat	3–5	4–6	80–85	Deadlift	3–5	4–6	80–85
Lunge	3–5	4–6	80–85	Midthigh clean pull	3–5	4–6	120–140
RDL	3–5	4–6	80–85	Leg press	3–5	4–6	80–85
Military press	3–5	4–6	BW	Chin-ups	3–5	4–6	BW
Drop landings	2–3	4–6	0.30 m box	Nordic curls	3	3	BW

BW = body weight; RDL = Romanian deadlift; Reps = repetitions; RM = repetition maximum.

Table 4
Example power training program

Session 1				Session 2			
Exercise	**Sets**	**Reps**	**Intensity (% 1RM)**	**Exercise**	**Sets**	**Reps**	**Intensity (% 1RM)**
Jump shrug	3–5	4–6	30–45[a]	Midthigh clean pull	3–5	4–6	40–60[a]
Deadlift	3–5	4–6	80–85	Back squat	3–5	4–6	80–85
Push press	3–5	4–6	50–70[a]	CMJ	3–5	4–6	BW
Depth jumps	3–5	4–6	BW	Nordics	3	3	BW

[a]Repetitions, sets, and loads are all recommendations from National Strength and Conditioning Association (2015) with exceptions of jump shrug (percent 1RM hang power clean) (84), push press (20), and midthigh clean pull (21).

BW = body weight; CMJ = countermovement jump; Reps = repetitions; RM = repetition maximum.

induced increases in measures of maximum strength have been shown to result in improved jump, sprint, and COD performances (58,72,76,89,91) while reducing MSA in weaker athletes (7). It is therefore likely that being equally proficient in producing and accepting GRFs on both limbs for jumping, sprinting, and COD will improve netball performance because of the number of high-intensity bouts, unilateral jump landings, and unpredicted COD.

Previous research has shown that improvements in relative strength improve sprint performances (76,91). Throughout a 20-week competitive season in female softball players (72), sprint performances were significantly faster (−1.7%, effect size [ES] = −0.20) from pre- to mid-training and 2.8% (ES = −0.53) from pre- to posttraining. In addition, absolute and relative back squat 1RM significantly increased with small-to-moderate effect from pre- to posttraining (10.3%, ES = 0.73; 12.2%, ES = 0.48, respectively) and from pre- to mid-training values (10.7%, ES = 0.65; 10.7%, ES = 0.39, respectively). Similar to findings in youth soccer players (18), Comfort et al. (19) found increases in relative strength were accompanied by improvements in sprint performance over 8 weeks of training in professional rugby league players.

High-power movements such as weightlifting exercises and similar movements such as depth jumps, jump squats, etc. are beneficial to improve netball-specific performance measures like jumping, sprinting, and COD because of the kinetic and kinematic similarities between the tasks (53,81,82). Although beneficial, many inconsistencies exist across research regarding the load to

Table 5
Example neuromuscular training program

Training phase	Training focus	Example exercise
Strength endurance mesocycle	Technique and landing mechanics—single plane	Bilateral exercises: drop landings, SJs in place, box jumps, broad jumps, forward jumps over hurdles
		Unilateral exercises: hop and holds, drop landings, split squats, walking lunges, reverse lunges, single-leg balance drills
Strength mesocycle	Eccentric and concentric strength—multiple plane	Bilateral exercises: drop landings, continuous jumps and stick, box jumps, broad jumps, lateral jumps over hurdles, zigzag jumps, 90° jumps
		Unilateral exercises: hop and holds, drop landings, walking lunges, reverse lunges, single-leg balance drills, 90° hops
Power mesocycle	Reactive strength—multiple plane	Bilateral exercises: depth jumps, depth jump to broad jump, continuous tuck jumps, continuous forward jumps over hurdles, box jumps, 180° jumps
		Unilateral exercises: continuous hop and stick, crossover hop, continuous lateral hops, split SJs, 180° hops

SJ = squat jump.

Table 6
Example HIT program

Training phase	Mode of HIT	Example session
Strength endurance mesocycle	Long and short intervals	LIT: 5 × 3-min intermittent running (90% MAS/77% V_{IFT}) interspersed with 90 s of passive recovery
		SIT: 2 sets of 12–15 × 15-s intermittent running (120% MAS/102% V_{IFT}) interspersed with 15 s of passive recovery
Strength mesocycle	Short intervals	2 sets of 12–15 × 15-s intermittent running (130% MAS/110% V_{IFT}) interspersed with 20 s of passive recovery
Power mesocycle	SSG	2 sets of 3–4 min games played 4 versus 4, interspersed with 2 min of passive recovery

HIT = high-intensity training; LIT = HIT with long intervals; MAS = maximal aerobic speed; SIT = HIT with short intervals; SSG = small-sided games; V_{IFT} = peak speed reached at the 30-15$_{IFT}$.

which produces optimum peak power output. Additionally, the optimal load may be specific to the exercise and joint, system, or bar power output (66). For example, during the clean pull from the floor, no difference in peak power has been observed between 90 and 120% 1RM power clean (40). In contrast, the greatest peak power output during the jump shrug occurs at 30–45% 1RM hang power clean (90), whereas the greatest peak power and velocity occur at 40% 1RM power clean during the midthigh clean pull (21). Peak power appears to occur at approximately 0–30% 1RM in jumping exercises (SJs, jump squats, loaded jumps, etc.) (23,65). Possible reasons for the inconsistencies in these findings are because of different measurement methods, knee angles, strength levels, and the varied training histories of subjects tested. Taken together, these findings indicate that to increase power, a variety of loading schemes for all exercises should be used and may be implemented (39). Furthermore, strength and power should be developed in a mixed manner to allow for a more complete adaptation across the entire force-velocity curve (39). Additionally, strength and power training should continue to be developed during the in-season, with recent work by Carr et al. (15) demonstrating the demands of the competitive cricket season and that current in-season training practices do not provide a sufficient stimulus to maintain strength, jump, and sprint performances in English county cricketers. Rønnestad et al. (74) found that professional soccer players who performed one strength maintenance training session per week were better able to maintain strength, sprint, and jump performances compared with players who performed one strength maintenance training session every second week. Similarly, Silvestre et al. (79) found that collegiate soccer players who performed strength and plyometric sessions maintained maximum strength, sprint, and jump performances across a 16-week competitive season. Taken collectively, these data indicate performing in-season strength and power training results in maintenance of maximum strength, sprint, and jump performances (Tables 2–5).

PRACTICAL APPLICATIONS: CONDITIONING TRAINING RECOMMENDATIONS

Anaerobic performance is of high importance in netball players in order to be first to the ball before an opponent, perform frequent accelerations, sprints, and jumps and to tolerate the pace of the game. Similarly, high levels of aerobic performance are needed to play the duration of the match, maintain the level of intensity throughout the match, and recover quickly between high-intensity bouts. A number of studies have found that HIT has shown to induce substantial improvements in maximal aerobic capacity and endurance performance (12,43). Billat (8) defined HIT as "repeated short (10 seconds to 1 minute) to long (2–4 minutes) bouts of rather high-intensity exercise interspersed with recovery periods." Numerous HIT modalities, including short intervals, repeated sprint training, sprint interval training, and SSGs, have been used to successfully develop aerobic endurance in team sport athletes (12,43). Research has found that 2 times per week 6–12 minutes of intermittent running for 15 seconds (95% V_{IFT}) interspersed with 15 seconds of passive recovery, for 10 consecutive weeks, improved V_{IFT} and mean repeated sprint time in young handball players (13). In the same study, the authors found handball-specific SSGs to be an equally effective training mode for training adolescent handball players. Handball-specific SSGs were organized in 4-a-side teams, consisting of 2–4 × 2 minutes 30 seconds to 4-minute games, for 10 consecutive weeks, with additional coach encouragement and rule modifications to avoid game interruption and promote a high intensity of exercises during play. Dupont et al. (29) found that 2 series of 12–15 intermittent runs at 120% maximal aerobic speed (MAS) interspersed with 15 seconds of passive recovery, performed 1 time per week for 10 consecutive weeks, significantly improved 40-m sprint time and MAS in professional soccer players. Dupont et al. (29) also found that performing 12–15, 40-m repeated sprints interspersed with 30 seconds of passive recovery, 1 time per week, also contributed to improved sprint and MAS performances. Furthermore, the soccer team won 77.8% of its games during the 10-week intervention period compared with 33.3% during the control period (normal technical and tactical skills, games, and matches). Buchheit et al. (14) found that performing sprint interval training for 4 consecutive weeks consisting of 3–6 repetitions of 30-second all-out shuttle sprints over 40 m, interspersed with 2 minutes of passive recovery, demonstrated improvements in V_{IFT} but only trivial changes in acceleration and repeated sprint measures, in well-trained male handball players. However, a number of studies show that the physiological responses to HIT sessions are highly variable and training modality specific (10). Therefore, choosing the "right" HIT modality, practitioners must consider (a) individual needs, (b) HIT responses to technical and skills sessions, and (c) integration into the micro- and mesocycle when selecting and implementing HIT sessions (Table 6).

CONCLUSIONS

It is highly recommended that netball players develop high levels of relative bilateral and unilateral strength and power because it is likely to transfer to sprint and jump performances while improving lower limb control to reduce the risk of common injuries. Netball players should use HIT methods to improve their aerobic and anaerobic endurances in line with the physiological demands of competition. More research is needed to better understand the workloads of netball players of different competition levels and the strength and power characteristics of netball players to establish normative values for monitoring and assessment of netball player's strengths and weaknesses.

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