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Abstract

Chandler, PT, Pinder, SJ, Curran, JD, and Gabbett, TJ. Physical demands of training and competition in collegiate netball players. *J Strength Cond Res* 28(10): 2732–2737, 2014—We investigated the physical demands of netball match play and different training activities. Eight collegiate netball players participated in the study. Heart rate (HR), rating of perceived exertion (RPE), and accelerometer player load (PL) data were collected in 4 matches and 15 training sessions. Training sessions were classified as skills, game-based, traditional conditioning, or repeated high-intensity effort training. Accelerometer data were collected in 3 planes and were normalized to match play/training time (PL per minute, forward per minute, sideward per minute, and vertical per minute). Centers had a higher PL per minute than all other positions (effect size; ES = 0.67–0.91), including higher accelerations in the forward (ES = 0.82–0.92), sideward (ES = 0.61–0.93), and vertical (ES = 0.74–0.93) planes. No significant differences ($p > 0.05$) were found between positions for RPE and peak HR. Skills training had a similar PL to match play. However, the mean HR of skills training was significantly lower than match play and all other modes of training (ES = 0.77–0.88). Peak HR for skills training (186 ± 10 $b \cdot min^{-1}$) and traditional conditioning (196 ± 8 $b \cdot min^{-1}$) was similar to match play (193 ± 9 $b \cdot min^{-1}$). There were no meaningful differences in RPE between match play and all modes of training. The center position produces greater physical demands during match play. The movement demands of netball match play are best replicated by skills training, whereas traditional conditioning best replicates the HR demands of match play. Other training modes may require modification to meet the physical demands of match play.

Key Words match play, accelerometry, team sport, movement demands, activity profiles

Introduction

Netball is a team sport that has one of the largest participation rates within the commonwealth, in particular the United Kingdom, Australia, and New Zealand (18), with more than 20 million athletes participating in the sport (8). Played on a 30.5 m × 15.25 m court, and with similar movement patterns to basketball, netball consists of four 15-minute quarters, with 5-minute rest at halftime and 3 minutes between other quarters. A netball team consists of 7 players on the court at one time. Each position has different court restrictions and roles within match play, which affects the physical demands of each position (7).

Time-motion analysis has been widely used to determine the physical demands of a range of team sports (1,14,15,17). A knowledge of sport demands is important for the applied sport scientist and strength and conditioning coach to develop game-specific conditioning programs to enhance performance.

To date, few studies have used time-motion analysis to investigate the match play demands of netball (7,10). Fox et al. (10) found the center (C) position to be more active than any other position; the goal keeper (GK) and goal shooter (GS) positions were least active (10). These findings are in agreement with Davidson and Trewartha (7) who investigated the physical demands of netball match play in 3 different positions (C, GS, and GK). The mean estimated total distance covered ranged from 4210 ± 477 (GS) to 7984 ± 767 m (C) (7). Players in the C position were found to cover a greater distance walking, jogging, shuffling, and running than the GS and GK positions (7).

Researchers have also monitored heart rate (HR) to investigate the physiological responses to netball training and match play (18). Almost 50% of match time was found to be at intensities between 75 and 85% of maximal HR, whereas the majority (43%) of training time was spent at a HR below 75% of maximal HR (18). These findings highlight that netball training does not adequately replicate the physical demands of match play. A limitation of this study was that all training activities were pooled in the analysis, and no attempt was made to identify the most and least demanding training activities. Previous research from other

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team sports has investigated different conditioning activities (traditional running activities without the ball, repeated high-intensity effort (RHIE) training, skills training, and game-based training) to determine the extent to which each of these activities replicated the demands of match play (12). Neither traditional conditioning, RHIE training, nor skills training reflected the physical demands of match play. However, game-based training offered the most specific method of conditioning, replicating the RHIE demands of competition, and exceeding the high-intensity running demands (12). It is likely that different conditioning exercises may also elicit different physical demands and physiological responses in netball; however, there are limited detailed data on the training and match demands of this sport.

To date, studies of the physical demands of netball have only investigated 3 playing positions (7); thus, the physical demands of all playing positions are poorly understood. In addition, although the previous studies pooled netball training activities and found significant differences between those performed in training and match play (7,18), it is unclear if specific conditioning activities (e.g., skills, game-based training, traditional conditioning, and RHIE training) could replicate match play demands. Without information on position and training-specific physical demands, the development of specific conditioning programs to maximize training adaptations becomes problematic.

With the emergence of microtechnology, methods other than video-based time-motion analysis are being used to study the physical demands of team sports. Accelerometers have been reported to have good reliability for the measurement of physical demands (3) and are increasingly used to measure the activity profiles of various team sports (4,5,16). To date, only 1 study has used this technology in netball (6). Combining the reliability of accelerometers with the ease of use allows the physical demands of netball to be readily monitored. Therefore, the aim of this study was to investigate the physical demands of different modes of netball training and compare these demands with match play. Furthermore, this study investigated the physical demands of specific playing positions during netball match play. Based on previous research (12), it was hypothesized that game-based conditioning would best replicate the physical demands of match play. It was also hypothesized that the center position would experience the greatest physical demands compared with all other positions, as the least court restrictions were imposed on this position.

Methods

Experimental Approach to the Problem

It is important to establish the physical demands of current training modes to determine if they replicate match play. Further identification of position physical demands is warranted to design netball-specific conditioning drills. Therefore, the aim of this study was to investigate the physical demands of different training modes and match play, as well as position-specific physical demands. To achieve this aim, the internal and external demands of collegiate level female netball players were studied using microtechnology units with in-built triaxial accelerometers, as well as ratings of perceived exertion (RPE) and average and maximum HR. Data were collected throughout the competitive phase of the season during match play, skills training, game-based training, traditional training, and RHIE training.

Subjects

Eight female collegiate-level netball athletes (age = 20.4 [18.8–22.0] years; body mass = 71.3 [61.9–80.7] kg; and height = 168.5 [160.4–176.6] cm) participated in the study. All athletes played netball for a minimum of 5 years before this study. In addition, before commencing the study, athletes had completed a 1 month general preparatory program consisting of aerobic conditioning, during the off-season. Consequently, all athletes were in good physical condition and free from injury. All data collection was performed during the in-season. All participants received a clear explanation of the study, and written consent was obtained. All study procedures were approved by the Edge Hill University ethics committee.

Procedures

The study investigated the physical demands of netball match play and different training modes (skills training, game-based training, traditional conditioning, and RHIE training) using accelerometers. Data were collected in 4 matches and 15 training sessions (Table 1) using a commercially available microtechnology unit (MinimaxX S4; Catapult Innovations, Melbourne, Australia). The unit included a triaxial accelerometer that sampled at 100 Hz. All positions (GK, goal defence [GD], wing defence [WD], center [C], wing attack [WA], goal attack [GA], and GS) wore a MinimaxX unit in a small vest on the upper back. Players wore the same MinimaxX unit during all testing. Heart rate was continuously monitored during match play and training using a Polar HR monitor (Team Heart Rate System, Polar, Kempele, Finland) to establish mean and peak HR. A rating of perceived exertion (RPE) was collected 15 minutes after match play and training session using a Borg CR10 scale (9).

Training data were categorized into skills training, game-based training, traditional conditioning, and RHIE training. Game-based training used reduced player numbers, larger playing area, and rule changes, aimed to develop and replicate physical demands, as well as technical skills and decision making under pressure and fatigue. Traditional conditioning consisted of interval and maximal aerobic speed training without a ball, whereas RHIE training involved repeated sprint, changes of direction, and jumping activities, with short (<21 seconds) recovery durations between efforts (12). Skills training aimed to develop core netball skills such as passing and catching and replicate movement patterns used in match play.

The MinimaxX unit measured the accumulation of accelerations in all 3 axes (sagittal, frontal, and transverse) of

Table 1. Training mode and number of data samples collected in collegiate netball players.

Training type/match play	No. samples	No. sessions
Match play	26	4
Skills training	24	3
Game-based training	40	5
Traditional conditioning	24	3
Repeated high-intensity effort training	32	4

movement to determine whole-body movement. This variable is referred to as player load (PL) (12) and has been proven to be highly reliable (coefficient of variation <2%) (3). Two variations of this variable were used to determine the physical demands: (a) total PL and (b) PL in each individual axis (frontal, forward; sagittal, sideward; transverse, vertical). All measurements of PL and PL forward, sideward, and up were normalized for match play/training time (minutes:seconds) and reported in arbitrary units (au·min^{-1}).

Statistical Analyses

Comparison of match play and training activities was performed using traditional null hypothesis testing and a practical approach based on the real-world relevance of the results. Data were checked for normality and homogeneity of variance using a Shapiro-Wilk's test of normality and Levene's test of variance. If tolerances were not met, the equivalent nonparametric test was used. Differences in physical demands (i.e., PL), and physiological and perceptual responses (i.e., mean HR, peak HR, and RPE) among playing positions during match play were compared using a 1-way analysis of variance (ANOVA) (PASW version 20 for Windows; IBM, Armonk, NY, USA). Where significant differences were detected, a Tukey post hoc test was used to determine the source(s) of those differences. Comparison of physical demands between match play and training type (i.e., skills training, game-based training, traditional conditioning and RHIE training) was analyzed using a repeated-measure ANOVA. Where significant differences were detected, a Tukey post hoc test was used to determine the source(s) of those differences. Cohen's effect size (ES) was used to calculate practically meaningful differences among playing positions and between match play and training modes. Effect sizes of <0.2, 0.2–0.6, 0.61–1.2, and >1.2 were considered trivial, small, moderate, and large, respectively (2). Data that were shown to be nonparametric (forward, sideward, vertical PL) were analyzed using a Kruskal-Wallis test, and comparison of significant multiple groups were performed using a Games-Howell post hoc test. The level of significance was set at $p \leq 0.05$, and all data are expressed as mean and 95% confidence intervals.

Results

Analysis of variance identified that all measured parameters had overall differences ($p < 0.01$), except for RPE ($p = 0.19$). Further post hoc analysis found that total PL for game-based

Table 2. Mean ± *SD* peak and mean HR, RPE, and PL for match play, skills training, game-based training, traditional conditioning, and RHIE.*

	Match play	Skills	Game-based training	Traditional conditioning	RHIE
Time (min)	55 (51.1–58.9)	61.8 (16.1–107.5)	10.2 (11.7–15.5)	18.49 (14.0–22.9)	1.7 (1.3–2.2)
Mean HR (b·min^{-1})	174 (170–177)†	144 (136–151)‡§‖	170 (167–172)	179 (174–183)	173 (171–176)
Peak HR (b·min^{-1})	193 (191–195)‡‖	186 (179–192)§	185 (183–187)§	196 (191–201)‖	187 (184–190)
RPE	5 (3–9)	4 (3–5)	4 (4–5)	5 (5–6)	5 (4–5)
PL/min	6.1 (3.0–3.9)‡§‖	6.0 (4.0–8.0)‡§‖	9.0 (8.4–9.6)§‖	18.5 (16.0–21.0)	16.6 (15.6–17.6)
Forward/min	2.3 (2.1–2.5)‡§‖	2.2 (1.6–2.8)‡§‖	3.8 (3.5–4.2)§‖	7.6 (5.7–9.5)‖	6.2 (5.4–6.9)
Sideward/min	2.4 (2.2–2.6)‡§‖	2.0 (1.3–2.6)‡§‖	3.5 (3.3–3.8)§‖	6.1 (5.4–6.8)‖	5.8 (5.3–6.2)
Vertical/min	4.2 (3.8–4.6)‡§‖	3.5 (2.5–4.6)‡§‖	7.6 (5.3–6.2)§‖	12.8 (11.4–14.3)‖	12.8 (12.0–13.8)

*Data are given as mean (95% confidence intervals). HR = heart rate; RPE = rate of perceived exertion; PL/min = player load per minute; forward/min = player load per minute in a frontal plane; sideward/min = player load per minute in a sagittal plane; vertical/min = player load per minute in a transverse plane; RHIE = repeated high-intensity efforts.
†Significant difference ($p \leq 0.05$) from skills training.
‡Significant difference ($p \leq 0.05$) from game-based training.
§Significant difference ($p \leq 0.05$) from traditional conditioning.
‖Significant difference ($p \leq 0.05$) from RHIE training.
¶Significant difference ($p \leq 0.05$) from match play.

Table 3. Mean and peak HR, RPE, and PL for each netball position during match play.*

	GK	GD	WD	C	WA	GA	GS
Time (min)	60.0 (0.0)	60.0 (0.0)	37.5 (27.7–39.8)	56.3 (48.9–63.6)	60.0 (0.0)	60.0 (0.0)	60.0 (0.0)
Mean HR (b·min^{-1})	172 (162–182)	174 (166–183)†	176 (172–181)†	185 (180–190)†‡	182 (176–188)†	156 (132–181)	167 (164–170)
Peak HR (b·min^{-1})	195 (193–200)	193 (187–199)	192 (192–200)	196 (180–204)	193 (192–193)	184 (177–190)	192 (189–194)
RPE	6 (3–9)	4 (0–8)	4 (2–6)	6 (4–9)	5 (4–7)	6 (1–10)	5 (3–7)
PL/min	3.5 (3.0–3.9)†§‖¶#	6.7 (6.2–7.2)‡¶#	6.5 (6.1–6.9)‡¶	9.6 (8.8–10.5)†‡#	5.1 (4.6–5.6)‡	6.5 (6.1–7.0)‡	3.4 (3.1–3.6)
Forward/min	1.4 (1.2–1.6)†§‖¶	2.4 (1.2–2.5)‡¶	2.1 (2.0–2.3)‡¶	3.8 (3.4–4.2)†‡#	1.8 (1.7–2.0)	2.2 (2.1–2.4)‡	1.5 (1.4–1.6)
Sideward/min	1.5 (1.3–1.7)†§‖¶#	2.7 (2.5–2.9)‡¶	2.7 (2.4–2.9)‡¶	3.4 (3.1–3.7)†‡#	2.2 (2.0–2.4)‡	2.5 (2.3–2.7)‡	1.4 ± (1.3–1.5)
Vertical/min	2.3 (2.0–2.6)†§‖¶	4.7 (4.3–5.1)‡¶	4.6 (4.3–4.9)‡¶	6.8 (6.2–7.5)†‡#	3.4 (3.1–3.8)	4.3 (3.62–5.0)‡	2.3 (2.1–2.5)

*Data are given as mean (95% confidence intervals). HR = heart rate; RPE = rate of perceived exertion; PL/min = player load per minute; forward/min = PL per minute in a frontal plane; sideward/min = PL per minute in a sagittal plane; vertical/min = PL per minute in a transverse plane; GK = goal keeper; GD = goal deference; WD = wing defence; C = center; WA = wing attack; GA = goal attack; GS = goal shooter.
†Significant difference ($p \leq 0.05$) from GA.
‡Significant difference ($p \leq 0.05$) from GS.
§Significant difference ($p \leq 0.05$) from GD.
‖Significant difference ($p \leq 0.05$) from WD.
¶Significant difference ($p \leq 0.05$) from C.
#Significant difference ($p \leq 0.05$) from WA.
**Significant difference ($p \leq 0.05$) from GK.

training (30.8 ± 2.9 au·min^{-1}), traditional conditioning (87.7 ± 4.6 au·min^{-1}), and RHIE training (25.3 ± 3.5 au·min^{-1}) was greater than match play; however, skills training (6.0 ± 1.3 au·min^{-1}) had similar PL to match play (6.1 ± 1.6 au·min^{-1}) (Table 2). The mean HR ($p < 0.01$; ES = −0.77) of skills training was significantly lower than match play and all other modes of training ($p < 0.01$; ES = 0.77–0.88). Peak HR for game-based training (186 ± 8 b·min^{-1}) and RHIE training (187 ± 10 b·min^{-1}) was significantly lower than match play, whereas peak HR for skills training (186 ± 10 b·min^{-1}) and traditional conditioning (196 ± 8 b·min^{-1}) was similar to match play (193 ± 9 b·min^{-1}). The forward, sideward, and vertical accelerations were higher than match play for game-based conditioning and RHIE training, but lower for traditional conditioning. No significant differences ($p = 0.99$) were found between match play and skills training for forward (2.2 ± 1.2 vs. 2.3 ± 0.9 au·min^{-1}), sideward (2.4 ± 1.1 vs. 2.4 ± 0.8 au·min^{-1}), and vertical (3.5 ± 2.0 vs. 4.2 ± 1.8 au·min^{-1}) accelerations. There were no meaningful differences between match play and any of the training modes for RPE ($p = 0.64$–1.23; ES = 0.0–0.18).

Analysis of variance found the overall differences for mean HR, PL, and PL in all axes ($p < 0.01$). Further post hoc testing found that the C position had greater PL than all other positions ($p < 0.01$; ES = 0.67–0.91) (Table 3). The GK and GS had lower PL than all other positions. The C position had a higher forward ($p < 0.01$; ES = 0.82–0.92), sideward ($p < 0.01$; ES = 0.61–0.93), and vertical ($p < 0.01$; ES = 0.74–0.93) PL than all other positions as identified by the post hoc analysis. GA ($p < 0.01$; ES = −0.79) and GS ($p < 0.01$; ES = −0.77) had significantly lower mean HR than the C position. Post hoc analysis found no significant difference between WD and WA for all measured parameters. Goal attack and GD also showed no significance between measured parameters, except mean HR with a small ES ($p = 0.04$; ES = −0.44). Analysis of variance found no significant differences between positions for RPE ($p = 0.23$) and peak HR ($p = 0.12$).

Discussion

This study is the first to investigate the physical demands of all netball positions during match play. In addition, we compared the physical demands of match play to different conditioning activities performed in netball training. Consistent with previous research (7,18), our results demonstrate differences in physical demands between playing positions. The GK and GS were found to have the lowest PL, suggesting lower physical demands of match play in these positions. These findings are in agreement with others (18) who reported that the GK and GS performed less total distance, including lower distances in jogging, running, and sprinting activities. Lower movement demands in the GK and GS positions may be because of court restrictions, with these players allowed in one-third of the court only. The link between court restrictions and physical demands is further highlighted by WA and WD, with similar physical demands and court restrictions. The C position has the least court restrictions and was found to have the greatest PL, suggesting the greatest physical demands during match play. Individual accelerometer data also showed that the C completed greater activity in all planes of movement than any of the other positions. These findings highlight that the C complete more multidirectional movement during match play. The difference in physical and movement demands between positions highlights the need for position-specific conditioning. The C position, for example, needs to complete a greater amount of work while incorporating more multidirectional movements compared with GK and GS positions. This may be achieved through the use of positional court restrictions and game-specific agility drills.

Skills training was found to replicate match play data for all parameters except mean HR, which was significantly lower than the demands of competition. Traditional conditioning was found to have a similar mean HR and also similar peak HR to match play; however, PL was greater than match play. Game-based training also displayed similar mean HR to match play with a greater PL. These findings suggest that skills training best replicates the movement demands of match play. These findings are in partial agreement with those of Montgomery et al. (16) who found lower mean HR and PL in specific basketball skills training than match play. Skills training has also been associated with lower relative distance and RHIEs than match play in other sports (12). Gabbett et al. (12) found that game-based conditioning produced the most specific form of conditioning, with similar RHIE demands and intensity of collisions to that observed in match play. However, these findings are in contrast to other sports (e.g., hockey and soccer) that found game-based conditioning was unable to replicate the repeated-sprint demands and time spent at higher speeds commonly observed in match play (13,14). Further contrast is evident from the measurement of PL. Greater accelerations were found in all planes of movement in game-based conditioning, RHIE training, and traditional conditioning compared with match play in this study, highlighting greater movement demands in all axes during these forms of training. Boyd et al. (4) found game-based conditioning to produce the best replication of Australian rules football match play PL; however, some positions exceeded match play PL. Collectively, these findings suggest that the specificity of conditioning activities differs between sports and most likely is related to the ability (or inability) of coaches to replicate those specific demands. Further research is needed to determine whether conditioning activities should be modified to replicate the demands of netball match play and whether game-specific training best prepares players for the demands of competition.

This study found no differences between playing positions or training modes and match play for RPE despite differences in physical activity profiles. This suggests that RPE is an insensitive measure of activity demands when compared with accelerometer data, or that all training activities elicited similar perceptions of effort, despite the differences in physical load. Montgomery et al. (16) also found no differences in RPE between skills training and match play despite differences in PL, providing further support that in isolation RPE may be an inadequate measure of training and match play demands. Session RPE (sRPE), the training time multiplied by the RPE of the session, is reliable and is regularly used to measure internal training load (9). An increase in training time would result in a greater sRPE, indicating a greater internal load. Therefore, sRPE may be able to identify differences in physical demands of playing position or training modes and match play.

A limitation of this study was that only 1 level of netball was examined. Previous research has found differences in physical demands between playing standards (11). In comparison with lower-standard players, Cormack et al. (6) found greater PL across all playing positions in higher standard netball players. These findings suggest that the movement demands of netball are greater at the elite than at the subelite level. Thus, the results of this study may not be transferable to other populations (i.e., elite level).

In conclusion, the physical and movement demands of netball differ among positions, but positions that have the same court restrictions tend to have similar physical and movement demands. This highlights the need for position-specific conditioning, which may use positional court restrictions to replicate physical demands. The movement demands of netball match play are best replicated by skills conditioning, whereas traditional conditioning best replicates the HRs observed during match play. Further research is needed to determine whether conditioning activities should be modified to replicate the physical and movement demands of netball match play and whether game-specific training best prepares players for the demands of competition.

Practical Applications

This study showed that the physical demands of match play differ between playing positions. Centers were found to have greater PL, including greater PL in all 3 axes, whereas GKs and GSs had the lowest PL. The WD and WA positions had similar physical demands for all measured parameters. These findings suggest that strength and conditioning coaches should individualize conditioning sessions to take into account the specific demands of each playing position. For example, a center's workload involves larger numbers of multidirectional movements than a GK. Preparing centers for these demands maybe achieved by incorporating positional court restrictions and multidirectional agility activities. Further consideration is also needed for the design of position-specific strength programs. Centers have an overall higher PL and complete a greater amount of short-recovery, high-intensity, multidirectional movements that are likely to stress the aerobic energy system. A strength-endurance program may be used to improve aerobic fitness, thereby conditioning centers for the demands of match play. Conversely, GKs and GSs perform high-intensity movements with longer recovery between efforts. These positions experience a low PL during match play, demonstrating a low work-to-rest ratio. These findings indicate a greater reliance on the alactic energy system, suggesting that a strength program aimed at developing speed and power would help meet the demands of match play for these positions.

There were no significant differences in RPE between playing positions or between training mode and match play, despite differences in physical activity profiles. These findings demonstrate an uncoupling of external and internal loads. Strength and conditioning coaches should be cautious when using RPE to quantify training and match loads as there is likely to be a mismatch in the physical and perceptual demands of training and competition.

Skills training was found to best replicate the movement demands of match play, whereas traditional conditioning best replicated the HRs observed during match play. Therefore, an integration of all training modalities may be necessary to effectively prepare netball players for the high-intensity demands of competition. However, during preparation for the competitive season, strength and conditioning coaches may need to overload athletes to induce positive training adaptations. This can be achieved through the use of small-sided games and RHIE drills, as these training methods produce greater physical demands than match play.

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