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Physical demands of training and competition in collegiate netball players

ABSTRACT

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 four matches and fifteen training sessions. Training sessions were classified as skills, game-based, traditional conditioning, or repeated high intensity effort training. Accelerometer data was collected in three planes, and was normalized to match-play/training time (PL/min, forward/min, sideward/min and vertical/min). Centres had a higher PL/min 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 beats·min^{-1}) and traditional conditioning (196 ± 8 beats·min^{-1}) were similar to match-play (193 ± 9 beats·min^{-1}). There were no meaningful differences in RPE between match-play and all modes of training. The centre position produces greater physical demands during match-play. The movement demands of netball match-play are best replicated by skills training, while traditional conditioning best replicates the HR demands of match-play. Other training modes may require modification in order 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 (19), with more than 20 million athletes participating in the sport (9). Played on a 30.5 m x 15.25 m court, and with similar movement patterns to basketball, netball consists of four 15 minute quarters, with five minutes rest at half time and three minutes between other quarters. A netball team consists of seven 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 (8).

Time motion analysis has been widely used to determine the physical demands of a range of team sports (1,15,16,18). A knowledge of sport demands is important for the applied sport scientist and strength and conditioning coach in order to develop game specific conditioning programmes to enhance performance.

To date, few studies have used time-motion analysis to investigate the match-play demands of netball (8,11). Fox et al. (11) found the centre (C) position to be more active than any other position; the goal-keeper (GK) and goal-shooter (GS) positions were least active (11). These findings are in agreement with Davidson and Trewartha (8) who investigated the physical demands of netball match-play in three different positions (C, GS and GK). The mean estimated total distance covered ranged from 4210 ± 477 m (GS) to 7984 ± 767 m (C) (8). Players in the C position were found to cover a greater distance walking, jogging, shuffling and running than the GS and GK positions (8).

Researchers have also monitored heart rate to investigate the physiological responses to netball training and match-play (20). Almost 50% of match time was found to be at intensities between

75% and 85% of maximal heart rate, while the majority (43%) of training time was spent at a heart rate below 75% of maximal heart rate (20). 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 team sports has investigated different conditioning activities (traditional running activities without the ball, repeated high-intensity effort training, skills training and game-based training) to determine the extent to which each of these activities replicated the demands of match-play (13). Neither traditional conditioning, repeated high-intensity effort training, nor skills training reflected the physical demands of match-play. However, game-based training offered the most specific method of conditioning, replicating the repeated high-intensity effort demands of competition, and exceeding the high-intensity running demands (13). It is likely that different conditioning exercises may also elicit different physical demands and physiological responses in netball; however there is limited detailed data on the training and match demands of this sport.

To date, studies of the physical demands of netball have only investigated three playing positions (8), thus the physical demands of all playing positions are poorly understood. In addition, while the previous studies pooled netball training activities and found significant differences between those performed in training and match-play (8,20), it is unclear if specific conditioning activities (e.g. skills, game-based training, traditional conditioning, and repeated high-intensity effort training) could replicate match-play demands. Without information on position and training-specific physical demands, the development of specific conditioning programmes 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 (4) and are increasingly employed to measure the activity profiles of various team sports (5,6,17). To date, only one study has used this technology in netball (7). 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 to match-play. Further, this study investigated the physical demands of specific playing positions during netball match-play. Based on previous research (13), it was hypothesized that game-based conditioning would best replicate the physical demands of match-play. It was also hypothesized that the centre position would experience the greatest physical demands compared to all other positions, as the least court restrictions were imposed on this position.

METHOD

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 tri-axial accelerometers, as well as ratings of perceived exertion (RPE) and average and maximum heart rate. Data was collected throughout the competitive phase of the season during match-play, skills training, game-based training, traditional training, and repeated high-intensity effort 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 five years prior to this study. In addition, prior to commencing the study, athletes had completed a one 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 repeated high-intensity effort training) using accelerometers. Data were collected in four matches and fifteen training sessions (Table 1) using a commercially available microtechnology unit (MinimaxX S4, Catapult Innovations, Melbourne, Australia). The unit included a tri-axial accelerometer that sampled at 100 Hz. All positions (goal-keeper (GK), goal-defence (GD), wing-defence (WD), centre (C), wing-attack WA), goal-attack (GA), and goal-shooter (GS)) wore a MinimaxX unit in a small vest, on the upper back. Players wore the same MinimaxX unit during all testing. Heart rate (HR) was continuously monitored during match-play and training using a Polar heart rate monitor (Team Heart Rate System, Polar, Finland) to establish mean and peak HR. A rating of perceived exertion (RPE) was collected fifteen minutes post match-play and training session using a Borg CR10 scale (10).

Insert Table 1 About Here.

Training data was categorized into skills training, game-based training, traditional conditioning and repeated high-intensity effort (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, while RHIE training involved repeated sprint, changes of direction and jumping activities, with short (<21 s) recovery durations between efforts (13). Skills training aimed to develop core netball skills such as passing and catching, and replicate movement patterns employed in match-play.

The minimaxX unit measured the accumulation of accelerations in all three axes (sagittal, frontal and transverse) of movement to determine whole body movement. This variable is referred to as player load (PL) (13), and has been proven to be highly reliable (coefficient of variation <2%) (4). Two variations of this variable were used to determine the physical demands: 1) Total PL, and 2) PL in each individual axes (frontal, forward; sagittal, sideward; transverse, up). 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).

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 was 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 non-parametric 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 one way ANOVA (PASW v20 for Windows). 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) were analyzed using a repeated measures 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. ES's 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 non-parametric (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 means and 95% confidence intervals.

RESULTS

ANOVA analysis identified all measured parameters had overall differences ($p < 0.01$), except for RPE ($p = 0.19$). Further post-hoc analysis found total PL for game-based training (30.8 ± 2.9 au/min), traditional conditioning (87.7 ± 4.6 au/min) and RHIE training (25.3 ± 3.5 au/min) were greater than match-play, however, skills training (6.0 ± 1.3 au) had similar PL to match-play (6.1 ± 1.6 au/min) (Table 2). The mean HR ($p < .01$; 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 beats·min^{-1}) and RHIE training (187 ± 10 beats·min^{-}

[1]) were significantly lower than match-play, while peak HR for skills training (186 ± 10 beats·min^{-1}) and traditional conditioning (196 ± 8 beats·min^{-1}) were similar to match-play (193 ± 9 beats·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 au/min *vs.* 2.3 ± 0.9 au/min), sideward (2.4 ± 1.1 au/min *vs.* 2.4 ± 0.8 au/min), and vertical (3.5 ± 2.0 au/min *vs.* 4.2 ± 1.8 au/min) 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).

Insert Table 2 About Here.

ANOVA analysis found overall differences for mean HR, PL and PL in all axes ($p < 0.01$). Further post-hoc testing found C 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. C 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 C. Post-hoc analysis found no significant difference between WD and WA for all measured parameters. GA and GD also showed no significance between measured parameters, except mean HR with a small effect size (p = 0.04; ES = -0.44). ANOVA analysis found no significant differences between positions for RPE (p = 0.23) and peak HR (p = 0.12).

Insert Table 3 About Here.

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 (8,20) 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 (20) 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 due to 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 C completed greater activity in all planes of movement than any of the other positions. These findings highlight that C complete more multidirectional movement during match-play. The difference in physical and movement demands between positions highlights the need for position specific conditioning. C, for example, need to complete a greater amount of work while incorporating more multidirectional movements compared to 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 (17) 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 repeated high-intensity efforts than match-play in other sports (13). Gabbett and colleagues (13) found that game-based conditioning produced the most specific form of conditioning, with similar repeated high-intensity effort 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 (14,15). 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 to match-play in this study, highlighting greater movement demands in all axes during these forms of training. Boyd et al (5) 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 differ between sports, and most likely is related to the ability (or inability) of coaches to replicate those specific demands. Further research is needed in order 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 to accelerometer data, or that all training activities elicited similar perceptions of effort, despite the differences in physical load. Montgomery et al. (17) 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 (10). 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 one level of netball was examined. Previous research has found differences in physical demands between playing standards (12). In comparison to lower standard players, Cormack et al (7) 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 the sub-elite 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 utilize positional court restrictions to replicate physical demands. The movement demands of netball match-play are best replicated by skills conditioning, while traditional conditioning best replicates the heart rates observed during match-play. Further research is needed in order 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

The present study showed that the physical demands of match-play differ between playing positions. Centres were found to have greater player load, including greater player load in all three axes, while goal-keepers and goal-shooters had the lowest player load. The wing-defence and wing-attack positions had similar physical demands for all measured parameters. These findings suggest that strength and conditioning coaches should individualize conditioning sessions in order to take into account the specific demands of each playing position. For example, a centre's workload involves larger numbers of multidirectional movements than a goal-keeper. Preparing centres' for these demands maybe achieved by incorporating positional court restrictions and multidirectional agility activities. Further consideration is need for the design of position specific strength programs. Centres complete a greater amount of high-intensity, multidirectional movements which stress the aerobic energy system. A strength-endurance program can improve aerobic fitness, thus better condition centres for the demands of match-play. Goal keepers and Goal Shooters show a low player load during match-play indicating a low work to rest ratio. This indicates a low frequency of high-intensity movements, thus 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, while traditional conditioning best replicated the heart rates 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 repeated high-intensity effort drills, as these training methods produce greater physical demands than match-play.

ACKNOWLEDGEMENTS

We thank Emily Williams for helping in data collection. The results of the present study do not constitute endorsement of the product by the authors or the journal.

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

Training type/ Match-play	Number of samples	Number of 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

Table 2. Mean ± standard deviation peak and mean heart rate, rating of perceived exertion, and player load for match-play, skills training, game based training, traditional conditioning and repeated high intensity effort training.

	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 (beats·min^{-1})	174 (170-177) $^{\times}$	144 (136-151) †,‡,#	170 (167-172)	179 (174-183)	173 (171-176)
Peak HR (beats·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)

Abbreviations: 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. Data are mean (and 95% confidence intervals).

* Significant difference (P<0.05) from Match-Play

× Significant difference (*P*<0.05) from Skills training

† Significant difference (*P*<0.05) from Game Based Training

‡ Significant difference (*P*<0.05) from Traditional Conditioning

Significant difference (*P*<0.05) from RHIE Training

Table 3. Mean and peak heart rate, rating of perceived exertion, and player load 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 (beats·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 (beats·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)

Abbreviations: 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; GK, goal keeper; GD, goal deference; WD, wing defence; C, centre; WA, wing attack; GA, goal attack; GS, goal shooter. Data are mean (and 95% confidence intervals).

* Significant difference (P<0.05) from GK

×	Significant difference (*P*<0.05) from GD
†	Significant difference (*P*<0.05) from WD
‡	Significant difference (*P*<0.05) from C
#	Significant difference (*P*<0.05) from WA
^	Significant difference (*P*<0.05) from GA
¤	Significant difference (*P*<0.05) from GS