Physical Demands of Amateur Domestic and Representative Netball in One Season in New Zealand Assessed Using Heart Rate and Movement Analysis

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Abstract

King, DA, Cummins, C, Hume, PA, and Clark, TN. Physical demands of amateur domestic and representative netball in one season in New Zealand assessed using heart rate and movement analysis. *J Strength Cond Res* XX(X): 000–000, 2018—The purpose of this descriptive cohort study was to describe physical demands of netball for positions and between playing levels using microtechnology. Data were collected from 34 female netball players across 3 teams at different levels (over 19 years representative [O19], under 19 years representative [U19], and open-age amateur club domestic) for 20 games using heart rate and microtechnology data. Total distance, maximal velocity, PlayerLoad ([PL] accumulated accelerometer-derived load), and individual PL vectors (PL forward [PL_F], PL sideward [PL_S] and PL vertical [PL_V]) were examined. Analysis by playing level and netball position were conducted. The O19 players recorded a higher mean distance (3,365.7 ± 1,875.1 m) per match than U19 ($p = 0.0095$) players. The O19 players recorded a higher PL ($p = 0.0003$), PL_F ($p = 0.004$), PL_S ($p = 0.0039$), and PL_V ($p = 0.0352$) than the domestic players. Domestic players recorded a higher maximal velocity than O19 players ($p = 0.0003$; $d = 0.32$) throughout the study. Domestic players recorded a higher average maximal heart rate (202.2 ± 28.2 b·min^{-1}) than O19 ($p < 0.0001$) and U19 ($p = 0.0002$) players. Given the high physical demands of netball, individual player- and position-specific training programs are required to develop players for the specific demands of competition while also reducing the impact of excessive physical exertion to facilitate safer engagement within netball. The identification of the differing physical and physiological profiles of individual positional groups throughout match-play highlights the importance of integrating microtechnology into the routine monitoring of intermittent court-based sports, such as netball.

Key Words accelerometery, movement demands, activity profiles, match-play, global positioning system

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Introduction

Netball can be classified as an intermittent court-based team sport that includes periods of both high (i.e., sprinting, jumping, and changing direction) and low intensity (i.e., walking, standing, and passing) (7). A typical netball match consists of 4 quarters ranging from 10 to 15 minutes, depending on playing level (ranging from recreational to international) and is played on either an indoor or an outdoor court measuring 30.5 m in length and 15.25 m in width. The aim of netball is to score a goal through an elevated ring, at the top of a 3.05-m high pole (7). The rules of netball necessitate that the game be played without any form of contact. Further, although players are able to take one step while in possession of the ball, they are unable to run when in possession. Players must also pass the ball to another team player within 3 seconds of attaining ball possession (7).

A netball team consists of 7 players who undertake unique roles (goal keep [GK], goal defence [GD], wing defence [WD], center [C], wing attack [WA], goal attack [GA], and goal shoot [GS]). Time-motion analysis has identified that the C spends a greater percentage of match-play being active than any other position, with the GK and GS being the least active. Using time-motion analysis and timing gates, it was found that the C (7,984 ± 767 m) traveled a greater distance than both the GK (4,210 ± 477 m) and the GS (4,283 ± 261 m) (9). Additionally, while the C has been reported to attain a greater work-to-rest

ratio (1:1.9) than both the GK (1:4.5) and the GS (1:2.9), all players change activity every 4.1 seconds of match-play (9). Collectively, such findings highlight the intermittent nature of netball and the necessity of players to compete with a range of skills, including aerobic capacity, agility, speed, and strength.

The incorporation of microtechnology (global positioning system [GPS] and integrated tri-axial accelerometer) devices has enabled the quantification of player movement patterns and activity profiles within team-sports (8). To date, most work examining the use of microtechnology devices has focused upon GPS-derived variables, such as distance covered, high-speed running, accelerations, and decelerations (8). These variables are, however, dependent on triangulation calculations from satellites and, therefore, are unable to be utilized within indoor sports, such as netball. In addition to the GPS chip, most microtechnology devices also contain a tri-axial accelerometer.

Research using microtechnology devices (accelerometer-based data only) has identified the movement demands of competition (6) and differences between levels of competition, halves, and positions (7). Such findings are, however, limited in that players were grouped into 3 broad categories of shooters, defenders, and centers (7), thereby inhibiting the ability to quantify and contrast the movement demands of individual playing positions (i.e., GK, GD, WD, C, WA, GA, and GS). Utilization of accelerometer-based data only provides limited insight into the true physical (i.e., distance covered) and physiological (i.e., heart rate [HR]) demands of netball. In addressing such limitations, a recent study has used microtechnology devices (both GPS- and accelerometer-based data) within youth netball (19).

Given the limited utilization of microtechnology within netball literature, the aim of this study was to quantify the movement demands and physiological responses of (a) individual positional groups and (b) between levels of competition within New Zealand.

Methods

Experimental Approach to the Problem

The movement demands and physiological responses of netball players in New Zealand at amateur premier club-based domestic level and amateur high-performance regional representative level of competition using GPS and HR accelerometers were measured during competition matches in 2016. Players at the amateur premier club-based domestic level participate in a club-based round robin competition, whereas the representative players were selected from these teams to form the respective regional representative competition teams participating in a national competition with other representative teams. The differences between playing positions and player levels were determined.

Subjects

Thirty-four (22.4 ± 4.3 years; range: 17–32 years) female domestic netball players (GK, GD, WD, C, WA, GA, and GS playing positions) volunteered for the study. This consisted of a domestic amateur premier one club-based team (± *SD*; $n = 11$; age: 25.6 ± 4.3 years), an under 19 years (U19) representative team ($n = 11$; age: 17.3 ± 0.9 years) and an over 19 years (O19) representative team ($n = 12$; age: 24.1 ± 2.4 years). All domestic, O19, and half of the U19 matches were played indoors on a sprung wooden floor. The other half of the U19 matches were played outdoors on a Rebound Ace surface over a concrete base. Players in the domestic amateur premier one club-based team participated in matches ($n = 10$) of four 15-minute quarters with a resulting match-exposure of 70 hours. Players in the U19 domestic representative team participated in matches ($n = 6$) of four 10-minute quarters with a resulting match-exposure of 31.5 hours. Players in the O19 domestic representative team participated in matches ($n = 4$) of four 10-minute quarters with a resulting match-exposure of 21 hours. Collectively, players had a combined match-exposure of 122.5 hours. The lead researchers' university ethics committee (Auckland University of Technology Ethics Committee 16/35) approved all procedures in the study, and all players and guardians of players under 18 years old gave informed written consent before participating in the study.

Procedures

Players' HR was continuously measured during match-play using a portable monitor (Team Heart Rate System; Polar, Kempele, Finland). Player movements were monitored using microtechnology devices (OptimEye S5 device; Catapult Innovations, Melbourne, Australia) worn in a custom designed pocket within a vest supplied by the device manufacturer, between the shoulder blades. The devices produce a 10-Hz GPS sampling rate through the in-built GPS chip. Additionally, the devices contain a tri-axial accelerometer, gyroscope, and magnetometer sampling at 100 Hz (firmware v.5.27). As such, the device can continuously monitor linear and rotational accelerations, direction, and orientation of the player during match-play. Postmatch data were downloaded and trimmed (to include on-court match-play time only) using proprietary software (Openfield; Catapult Innovations). The OptimEye S5 has been previously reported to have valid and reliable distance and speed measurements and have nearly perfect correlation ($r = 0.94$) with distance covered and acceptable within- and between-device reliability for measuring acceleration forces (1,2,15,20).

Given that most netball matches (90%) were played indoors, the calculation of GPS-based metrics (distance and maximal velocity) within the study was checked via inspection of the underlying GPS data to ensure satellite lock. The clear roof of the netball stadium enabled the microtechnology devices to attain satellite lock and maintain a high signal strength throughout all indoor matches.

Mean and peak HR for each match were calculated for each player. During each match, the following time and GPS-based variables were analyzed: match time (minute), total distance (meter) and maximum velocity ([Vel_{Max}]

Table 1. Summary of movement demands and physiological responses (mean ± *SD*) of domestic and representative amateur netball players over a season of competition matches and representative tournaments by mean with *SD*.*

	Domestic	U19 rep	O19 rep	Total
Players (n)	11	11	12	34
Age (y)	25.6 ± 4.3†	17.3 ± 0.9‡§	24.1 ± 2.4	22.4 ± 4.3
Games (n)	10	6	4	20
Time of game quarters	15 min†§	10 min‡	10 min‡	–
Match-exposure (hours)	70†§	31.5‡	21‡	122.5
Match time per player (min)	45.3 ± 17.4	30.2 ± 9.3	29.8 ± 9.6	37.8 ± 16.0
Distance (m)	4,470 ± 2,680	2,697 ± 1,579§	3,366 ± 1,875†	3,752 ± 2,381
PL ($au \cdot min^{-1}$)	6.5 ± 2.2§	7.2 ± 3.6	7.4 ± 3.5‡	8.5 ± 3.6
2DPL ($au \cdot min^{-1}$)	3.9 ± 1.2	4.6 ± 2.3	4.7 ± 2.2	5.6 ± 2.1
PLFwd ($au \cdot min^{-1}$)	2.4 ± 0.8§	2.8 ± 1.4§	2.8 ± 1.3†‡	3.2 ± 1.3
PLSide ($au \cdot min^{-1}$)	2.6 ± 0.8§	3.0 ± 1.5§	3.1 ± 1.5†‡	3.5 ± 1.4
PLUp ($au \cdot min^{-1}$)	4.5 ± 1.6§	4.9 ± 2.5	5.0 ± 2.5‡	5.9 ± 2.6
Vel_{Max} ($m \cdot s^{-1}$)	5.6 ± 3.8§	3.5 ± 1.3	4.5 ± 3.1‡	4.5 ± 3.1
HRmax ($b \cdot min^{-1}$)	202 ± 28†§	185 ± 33‡§	168 ± 71†‡	190 ± 46
HRmean ($b \cdot min^{-1}$)	141 ± 15	136 ± 21	116 ± 46	134 ± 29

*U19 rep = under 19 years representative; O19 rep = over 19 years representative; $au \cdot min^{-1}$ = arbitrary units per minute; PL = PlayerLoad; 2DPL = 2-dimensional (frontal and sagittal) playerload; PLFwd = player load in frontal plane; PLSide = playerload in sagittal plane; PLUp = playerload in transverse plane; Vel_{Max} ($m \cdot s^{-1}$) = maximum velocity (meters per second); HR = heart rate.
†Significantly different ($p < 0.05$) = U19 rep.
‡Significantly different ($p < 0.05$) = domestic.
§Significantly different ($p < 0.05$) = O19 rep.

$m \cdot s^{-1}$). Additionally, accumulated accelerometer-derived loads (arbitrary unit known as PlayerLoad [PL]) were calculated by the sum of accelerations in the mediolateral (x), anteroposterior (y), and vertical (z) directions to provide a measure of the total stress upon an athlete as a result of accelerations, decelerations, changes of direction, and impacts (2,21).

PlayerLoad is expressed as the square root of the sum of the squared instantaneous rate of change in each of the 3 vectors. The application of this variable as a marker of training load has been established against both internal (5) and external load (16) measures. PlayerLoad has previously been shown to be reliable both between (1.02% coefficient of variation [CV]) and within devices (1.05% CV) for dynamic movements (9). Further, within a team sport circuit, the reliability of PL was reported as 4.9% CV. Additionally, PL demonstrates high interunit reliability within Australian Rules Football (1.94% CV) (9). There is a strong relationship between PL and total distance (3), and as such, the vertical vector of the PL equation can be removed, thereby providing a measure of acceleration in the mediolateral and anterior-posterior planes only (2-dimensional player load [2DPL]) (13,14). The PL and 2DPL were recorded, and the PL in each of the individual axes, i.e., PL forward (PL_F), PL sideward (PL_S) and PL vertical (PL_V), was recorded. Each PL variable was normalized for all match times (minutes) and reported in arbitrary units ($au \cdot min^{-1}$).

Statistical Analyses

All data were analyzed with SPSS (IBM Corp., Released 2017. IBM SPSS Statistics for Windows, version 24.0, Armonk, NY: IBM Corp.). Data were checked for normality and homogeneity of variance using a Shapiro-Wilk's test of normality. If tolerances were not met, equivalent nonparametric tests were used. Physical demands (i.e., PL, PL2D, PLG_F, PL_S, PL_V, and Vel_{Max}) among player positions and participation levels were compared using a 1-way analysis of variance (ANOVA) with a Tukey post hoc test to determine the source of differences. Nonparametric data (distance, HRmax, and HRmean) were analyzed with a Friedman repeated-measures ANOVA on ranks. If notable differences were observed, a Wilcoxon signed rank post hoc test was conducted with a Bonferroni correction applied. Cohen's effect size (d) was used to calculate practically meaningful differences between playing positions and for different levels of participation. Effect sizes of <0.19, 0.20–0.60, 0.61–1.20, and >1.20 were considered trivial, small, moderate, and large, respectively (11). The level of significance was set at $p \leq 0.05$, and all data are expressed as mean values and *SD*s.

Results

Player Characteristics and Exposure to Netball Matches

The domestic and O19 players were similar in age, whereas the U19 representative team players were significantly younger than the other 2 groups. Exposure to netball

Table 2. Summary of movement demands and physiological responses (mean ± *SD*) of domestic and representative amateur netball players by player position over a season of competition matches and representative tournaments by mean with *SD*.*

	GK	GD	WD	C	WA	GA	GS
Domestic							
Match time (min)	49.6 ± 15.5	45.0 ± 18.7	43.8 ± 17.6	46.5 ± 16.5	40.8 ± 18.4	48.2 ± 17.0	42.0 ± 18.4
Distance (m)	4,741.4 ± 3,275.3†	2,890.4 ± 1,379.5†	4,363.6 ± 2,619.7†	8,367.4 ± 2,565.8‡§‖¶#**	4,261.8 ± 2,154.4†	3,236.7 ± 1,415.0†	4,737.6 ± 2,544.7†
PL (au·min^{-1})	9.2 ± 7.1	9.1 ± 6.6#	10.9 ± 7.8	16.4 ± 10.3	13.7 ± 10.1	9.5 ± 6.6§**	11.2 ± 6.7#
2DPL (au·min^{-1})	5.3 ± 4.1	5.6 ± 4.0‖#	6.6 ± 4.8§	9.5 ± 6.1	8.7 ± 6.5	5.7 ± 3.9§**	7.0 ± 4.3#
PLFwd (au·min^{-1})	3.0 ± 2.5§	3.3 ± 2.4‡**	4.0 ± 3.0	5.9 ± 3.8	5.5 ± 4.2	3.4 ± 2.2**	4.1 ± 2.6§#
PLSide (au·min^{-1})	3.7 ± 2.6‖†	3.8 ± 2.7†#	4.4 ± 3.1†‡	6.1 ± 4.0‡§‖#	5.6 ± 4.0#	3.8 ± 2.7†§¶**	4.7 ± 2.9#
PLUp (au·min^{-1})	6.5 ± 5.1†	6.2 ± 4.5	7.6 ± 5.4†¶	11.7 ± 7.2‡‖#	9.2 ± 6.8‖	6.6 ± 4.7†**	7.7 ± 4.5#
Vel_{Max} (m·s^{-1})	6.1 ± 4.1	4.4 ± 0.8	5.7 ± 3.6	8.9 ± 5.8	5.4 ± 3.7#	3.9 ± 0.5¶	6.2 ± 4.9
HRmax (b·min^{-1})	195 ± 33.8	208.0 ± 7.1	192.1 ± 48.9**	211.5 ± 20.3	206.9 ± 33.5	202.1 ± 23.5	174.6 ± 42.6‖
HRmean (b·min^{-1})	131 ± 16.0†§	148.0 ± 9.8‡	133.4 ± 32.8	145.1 ± 8.5‡	146.4 ± 18.0	136.5 ± 17.9	137.4 ± 13.6
U19 representative							
Match time (min)	35.0 ± 5.8	36.0 ± 5.5	30.0 ± 8.9	27.5 ± 8.7	32.5 ± 9.6	27.5 ± 12.2	28.8 ± 9.9
Distance (m)	3,341 ± 1,062	4,443 ± 1,408†#	2,703 ± 1,461	2,331 ± 1,193§	4,148 ± 1,937	1,945 ± 1,641§	2,232 ± 1,240
PL (au·min^{-1})	9.8 ± 3.7	11.4 ± 1.8	7.3 ± 1.5	12.4 ± 7.3	11.9 ± 2.8	13.2 ± 16.4	9.4 ± 6.9
2DPL (au·min^{-1})	6.3 ± 2.4	7.3 ± 1.2	4.7 ± 0.9	7.7 ± 4.5	7.8 ± 1.8	8.2 ± 10.3	5.8 ± 4.2
PLFwd (au·min^{-1})	3.9 ± 1.7	4.4 ± 0.7	2.9 ± 0.6	4.8 ± 2.8	4.9 ± 1.2	5.1 ± 6.6	3.4 ± 2.6
PLSide (au·min^{-1})	4.1 ± 1.4	4.9 ± 0.8	3.0 ± 0.6	5.0 ± 3.0	4.9 ± 1.1	5.4 ± 6.5	4.0 ± 2.8
PLUp (au·min^{-1})	6.5 ± 2.5	7.6 ± 1.2	4.9 ± 1.0	8.4 ± 5.1	7.9 ± 2.1	9.0 ± 11.1	6.4 ± 4.8
Vel_{Max} (m·s^{-1})	2.8 ± 0.5	4.0 ± 0.7	3.2 ± 0.8	3.7 ± 1.2	4.3 ± 0.4	3.1 ± 1.9	3.5 ± 1.3
HRmax (b·min^{-1})	201 ± 20	212 ± 20	153 ± 32	169 ± 34	195 ± 33	189 ± 36	198 ± 21
HRmean (b·min^{-1})	138 ± 22	150 ± 11	135 ± 15	131 ± 27	131 ± 24	132 ± 20	145 ± 15
O19 representative							
Match time (min)	32.0 ± 8.4	27.5 ± 12.6	34.3 ± 7.9	40.0 ± 0.0	32.0 ± 10.3	28.3 ± 7.5	25.7 ± 11.3
Distance (m)	2,846 ± 944‖	5,515 ± 1,472	2,049 ± 2,764†‡	4,414 ± 1,415‖	3,393 ± 1,765	3,396 ± 1,266	3,162 ± 1,475
PL (au·min^{-1})	7.6 ± 2.5	21.8 ± 12.7	6.7 ± 5.4	10.2 ± 3.5	9.6 ± 4.8	12.0 ± 5.4	11.6 ± 7.9
2DPL (au·min^{-1})	5.1 ± 1.8	13.4 ± 7.4	4.3 ± 3.4	6.2 ± 6.1	6.2 ± 3.1**	7.7 ± 3.5	7.3 ± 4.9¶
PLFwd (au·min^{-1})	3.2 ± 1.3	7.8 ± 4.0	2.6 ± 2.0	3.6 ± 1.2**	3.8 ± 2.0**	4.7 ± 2.1	4.2 ± 2.8†¶
PLSide (au·min^{-1})	3.2 ± 1.0¶	9.2 ± 5.4	2.8 ± 2.2¶	4.2 ± 1.5	4.1 ± 1.9‡‖**	5.1 ± 2.3	5.0 ± 3.5¶
PLUp (au·min^{-1})	5.0 ± 1.5	15.2 ± 9.2	4.5 ± 3.7**	7.1 ± 2.4	6.4 ± 3.2**	8.0 ± 3.5	7.8 ± 5.4‖¶
Vel_{Max} (m·s^{-1})	3.0 ± 0.3	3.2 ± 0.4	2.0 ± 0.9	2.9 ± 0.6	3.3 ± 2.1	3.5 ± 2.3	3.3 ± 0.5
HRmax (b·min^{-1})	133 ± 23	187 ± 44	203 ± 27	207 ± 17	194 ± 40	214 ± 16	184 ± 38

HRmean ($b \cdot min^{-1}$)	117 ± 17	130 ± 17	137 ± 27	142 ± 11¶	129 ± 21†	134 ± 15	133 ± 17
Combined total							
Match time (min)	43.6 ± 15.0	38.9 ± 16.1	39.7 ± 16.2	35.4 ± 15.2	36.8 ± 15.5	38.2 ± 17.4	33.1 ± 15.3
Distance (m)	4,069 ± 2,748	3,851 ± 1,726	3,302 ± 2,481	4,951 ± 3,421#	4,219 ± 2,013	2,844 ± 1,565†	3,502 ± 2,109
PL ($au \cdot min^{-1}$)	8.6 ± 5.7	12.4 ± 8.7‖	8.4 ± 6.5§	15.3 ± 10.6	12.3 ± 8.0	11.1 ± 10.5**	10.9 ± 6.8#
2DPL ($au \cdot min^{-1}$)	5.3 ± 3.3	7.7 ± 5.2‖#	5.3 ± 4.0§#	9.2 ± 6.4	7.8 ± 5.2**	6.8 ± 6.6§‖**	6.8 ± 4.3¶#
PLFwd ($au \cdot min^{-1}$)	3.1 ± 2.0§**	4.5 ± 3.0‡‖	3.2 ± 2.4§	5.6 ± 3.8#	4.9 ± 3.4	4.2 ± 4.1†**	4.0 ± 2.5‡#
PLSide ($au \cdot min^{-1}$)	3.5 ± 2.1§†	5.2 ± 3.7‡‖	3.4 ± 2.6§	6.0 ± 4.3‡#	5.1 ± 3.2**	4.5 ± 4.2†**	4.6 ± 2.9¶#
PLUp ($au \cdot min^{-1}$)	6.0 ± 4.1†	8.5 ± 6.1	5.8 ± 4.5¶	10.7 ± 7.5‡#	8.2 ± 5.4‖	7.6 ± 7.2†**	7.4 ± 4.6#
Vel_{Max} ($m \cdot s^{-1}$)	4.9 ± 3.6	4.0 ± 0.9†**	4.4 ± 3.2†**	5.7 ± 4.5§‖**	4.6 ± 3.1#	3.6 ± 1.4¶	4.5 ± 3.4§‖†
HRmax ($b \cdot min^{-1}$)	182 ± 41§¶	204 ± 22‡	200 ± 28**	192 ± 34.2	201 ± 35‡	200 ± 27	184 ± 35‖
HRmean ($b \cdot min^{-1}$)	130 ± 18§¶	144 ± 14‡	140 ± 14	138 ± 20.2	140 ± 21‡‡	135 ± 18	137 ± 15

*GK = goal keep; GD = goal defence; WD = wing defence; C = center; WA = wing attack; GA = goal attack; GS = goal shoot; PL = PlayerLoad; $au \cdot min^{-1}$ = arbitrary units per minute; 2DPL = 2-dimensional (frontal and sagittal) player load; PLFwd = player load in frontal plane; PLSide = player load in sagittal plane; PLUp = player load in transverse plane; Vel_{Max} ($m \cdot s^{-1}$) = maximum velocity (meters per second); HR = heart rate.

†Significant difference ($p < 0.05$) = center.

‡Significant difference ($p < 0.05$) = goal keep.

§Significant difference ($p < 0.05$) = goal defence.

‖Significant difference ($p < 0.05$) = wing defence.

¶Significant difference ($p < 0.05$) = wing attack.

#Significant difference ($p < 0.05$) = goal attack.

**Significant difference ($p < 0.05$) = goal shoot.

matches was greater for the domestic team given that each match was 60 minutes in duration; therefore, normalization was conducted for player match-exposure.

Playing Level–Movement Demands and Physiological Responses

Movement demands and physiological responses between levels of competition (O19 representative, U19 representative, and domestic) within New Zealand were assessed (Tables 1 and 2). The O19 players recorded a higher mean distance (3,366 ± 1,875 m) per match than U19 players ($\chi^2_{(1)} = 6.7$; $p = 0.0095$; $z = -2.2$; $p = 0.0255$; $d = 0.33$; Table 1). The O19 players recorded a higher PL ($F_{(32,10)} = 9.6$; $p = 0.0003$; $d = 0.31$), PL_F ($F_{(26,16)} = 3.7$; $p = 0.0041$; $d = 0.37$), PL_S ($F_{(30,12)} = 4.6$; $p = 0.0039$; $d = 0.42$), and PL_V ($F_{(29,13)} = 2.6$; $p = 0.0352$; $d = 0.24$) than the domestic players. Domestic players recorded a higher Vel_{Max} than O19 players ($F_{(30,12)} = 7.8$; $p = 0.0003$; $d = 0.32$) over the duration of the study. Domestic players recorded a higher average HRmax (202 ± 28 b·min^{-1}) than O19 ($\chi^2_{(1)} = 18.8$; $p < 0.0001$; $z = -4.3$; $p < 0.0001$; $d = 0.63$) and U19 ($\chi^2_{(1)} = 13.6$; $p = 0.0002$; $z = -2.1$; $p = 0.0335$; $d = 0.56$) players.

Playing Level by Position

Domestic Players. The C recorded a higher mean distance (8,367 ± 2,566 m) per match than WD ($\chi^2_{(1)} = 10.0$; $p = 0.0016$; $z = -2.8$; $p = 0.0050$; $d = 1.5$) and GA ($\chi^2_{(1)} = 10.0$; $p = 0.0016$; $z = -2.8$; $p = 0.0051$; $d = 2.5$) (Table 2). As a result, the C recorded a higher mean PL_S (6.1 ± 4.0 au·min^{-1}) and PL_V (11.7 ± 7.2 au·min^{-1}) than the WD (PL_S: $F_{(8,1)} = 1{,}729.3$; $p = 0.0182$; $d = 0.5$; PL_V: $F_{(8,1)} = 4{,}9775.8$; $p = 0.0340$; $d = 0.6$) and GA (PL_S: $F_{(8,1)} = 715.6$; $p = 0.0289$; $d = 0.67$; PL_V: $F_{(8,1)} = 516.8$; $p = 0.0340$; $d = 0.8$). The WA recorded a higher mean Vel_{Max} (5.4 ± 3.7 m·s^{-1}) than the GA ($F_{(11,6)} = 4{,}384.1$; $p < 0.0001$; $d = 0.9$). The WD recorded a higher mean HRmax (192 ± 49 b·min^{-1}) when compared with the GS ($\chi^2_{(1)} = 6.4$; $p = 0.0114$; $z = -2.2$; $p = 0.0281$; $d = 0.5$), whereas the GK recorded the lowest HRmean (131 ± 16 b·min^{-1}) when compared with the C ($\chi^2_{(1)} = 4.5$; $p = 0.0339$; $z = -2.1$; $p = 0.0357$; $d = -1.9$) and the GD ($\chi^2_{(1)} = 4.5$; $p = 0.0039$; $z = -2.1$; $p = 0.0339$; $d = -2.1$) per match.

U19 Representative Players. The U19 GD recorded a higher mean distance (4,443 ± 1,408 m) than the C ($\chi^2_{(1)} = 4.5$; $p = 0.0339$; $z = -2.1$; $p = 0.0357$; $d = 1.6$) and the GA ($\chi^2_{(1)} = 4.5$; $p = 0.0039$; $z = -2.4$; $p = 0.0173$; $d = 1.6$) per match (Table 2). Although the GA recorded a higher mean PL (13.2 ± 16.4 au·min^{-1}) and 2DPL (8.2 ± 10.3 au·min^{-1}) and a lower mean Vel_{Max} (3.1 ± 1.9 m·s^{-1}) per match than the C (PL: $F_{(10,1)} = 0.38$; $p = 0.8638$; $d = 0.1$; 2DPL: $F_{(7,1)} = 1.1$; $p = 0.6341$; $d = 0.1$; Vel_{Max}: $F_{(10,1)} = 3.2$; $p = 0.4134$; $d = 0.4$), these were not significant.

O19 Representative Players. The WD recorded a lower mean distance (2,049 ± 2,764 m) than the C ($\chi^2_{(1)} = 5.0$; $p = 0.0253$; $z = -2.0$; $p = 0.0431$; $d = -1.1$) and the GA ($\chi^2_{(1)} = 5.0$; $p = 0.0253$; $z = -2.0$; $p = 0.0431$; $d = -0.6$) per match (Table 2). The WD recorded a lower mean PL_S (2.8 ± 2.2 au·min^{-1}) than the WA ($F_{(5,1)} = 1{,}654$; $p = 0.0187$; $d = -0.6$), and GS recorded a higher mean PL_V (7.8 ± 5.4 au·min^{-1}) than the WA ($F_{(4,2)} = 53.7$; $p = 0.0184$; $d = 0.3$) and the WD ($F_{(4,2)} = 24.6$; $p = 0.0395$; $d = 0.7$). The C recorded a higher mean Vel_{Max} (3.7 ± 1.2 m·s^{-1}) than WD ($F_{(20,4)} = 216.3$; $p < 0.0001$; $d = 0.3$), GD ($F_{(13,5)} = 269.7$; $p < 0.0001$; $d = 0.5$), and GS ($F_{(20,4)} = 56.4$; $p = 0.0007$; $d = 0.3$) per match. The C recorded a higher HRmean (141 ± 11 b·min^{-1}) than WA ($\chi^2_{(1)} = 5.0$; $p = 0.0253$; $z = -2.0$; $p = 0.0431$; $d = 0.8$) per match.

Positional Groups–Without Level Indicated (ALL)

Across all positional groups, without competition level included (Table 2), C recorded a higher mean distance (4,951 ± 3,421 m) per match than GA ($\chi^2_{(1)} = 6.8$; $p = 0.0093$; $z = -2.7$; $p = 0.0074$; $d = 0.8$). The WD recorded a lower mean PL_F (4.2 ± 4.1 au·min^{-1}), PL_S (4.5 ± 4.2 au·min^{-1}), and PL_V (7.6 ± 7.2 au·min^{-1}) when compared with GA (PL_F: $F_{(22,2)} = 41.2$; $p = 0.0238$; $d = 0.4$; PL_S: $F_{(22,2)} = 79.5$; $p = 0.0125$; $d = 0.4$; PL_V: $F_{(22,2)} = 21.8$; $p = 0.0448$; $d = 0.4$). The C recorded a higher Vel_{Max} (5.7 ± 4.5 m·s^{-1}) per match than WD ($F_{(20,4)} = 216.3$; $p < 0.0001$; $d = 0.3$), GD ($F_{(13,5)} = 269.7$; $p < 0.0001$; $d = 0.5$), and GS ($F_{(20,4)} = 56.4$; $p = 0.0007$; $d = 0.3$). The GK recorded the lowest HRmax (182 ± 41 b·min^{-1}) and HRmean (130 ± 18 b·min^{-1}) per match when compared with WA (HRmax: $\chi^2_{(1)} = 5.4$; $p = 0.0201$; $z = -2.2$; $p = 0.0267$; $d = 0.5$; HRmean: $\chi^2_{(1)} = 5.4$; $p = 0.0201$; $z = -2.3$; $p = 0.0231$; $d = 0.5$) and GD (HRmax: $\chi^2_{(1)} = 4.6$; $p = 0.0325$; $z = -2.0$; $p = 0.0412$; $d = 0.7$; HRmean: $\chi^2_{(1)} = 4.6$; $p = 0.0325$; $z = -2.6$; $p = 0.0092$; $d = 0.9$) per match.

Discussion

The study reports the physical demands of amateur domestic and representative netball players, by player position, in New Zealand during match-play. The results identify the physical and physiological profile of individual positional groups throughout match-play. Given the current limited availability of both GPS- and accelerometer-based variables with netball, this work highlights the importance of integrating microtechnology into the routine monitoring of intermittent court-based sports such as netball.

Previous studies of netball players have been undertaken at the collegiate (6), sub-elite (7), and professional levels (9,10,18,22) of participation, but, to date, no published studies have been reported on amateur domestic and representative players in New Zealand. The findings of this study are similar to previous studies (6,7,9,10,18,22), in that there were differences in the physical demands between different playing positions but what was not expected were the differences identified between the different levels of participation. This may be related to the number of matches the domestic players participated in when compared with the U19 and O19 players. The GK and WD had the lowest mean PL suggesting that there were lower physical demands of match-play

for these positions. This is similar to previous studies (6,18,22) where the GK had the lowest mean PL, but they also reported the GS as having the lowest PL, which was not the case in the current study. When compared by the different levels of participation, the position with the lowest PL also varied. The U19 WD and GS had the lowest mean PL, whereas the domestic and O19 GK and WD players recorded the lowest mean PL. The finding that the GK had the lowest mean PL may be related to rule-imposed limitations whereby this position was allowed in one-third of the court only (6). This may also be reflected in the mean PL for the WA and WD where there are similar rule-imposed limitations (6), whereas the C has the least rule-imposed limitations and was found to have the highest mean PL overall. Again, this varied by participation level with the O19 GD recording the highest mean PL. Together, the findings of this study highlight the practical applications reported by Chandler et al. (6), in that individualized conditioning sessions should take into account the specific demands of the different playing positions in netball at all levels of participation. Although not undertaken in this study, the use of microtechnology to measure the physical demands undertaken during training sessions could assist with monitoring and tailoring conditioning sessions to the match-play demands of individual playing positions. As such, further research is warranted during training sessions of amateur netball players.

Domestic players recorded the highest mean distance, Vel_{Max}, HRmax, and HRmean, yet the lowest PL and 2DPL when compared with the U19 and O19 representative players. This may be related to the number of matches the domestic players participated in when compared with the U19 and O19 players. The current study identified that the PL was higher in the representative (U19, O19) when compared with domestic players. This is similar to previous research in netball (7), field hockey (12), Australian rules football (4), and rugby league (17), where higher level players exhibited greater levels of PL when compared with players from lower levels of match participation. Similar to these studies (4,7,17), the specific movements responsible for the increased PL remains unclear; however, more frequent bouts of high-speed running have been implicated. As previously reported (7), there is a strong relationship between total distance and PL; however, the size of the netball court in addition to the games rules may result in different movement patterns when compared with sports such as Australian football and rugby league, which provide an increased opportunity to accrue distance because of the larger sporting fields. Despite the increased PL in the U19 and O19 players, the domestic players recorded a higher mean distance but had a lower mean PL, indicating that distance covered may not be the only aspect influencing PL. Given the change of direction, side-stepping, and jumping movements undertaken within netball, further investigation into the relationship between such movements, total distance, and PL is warranted.

The higher mean PL and lower mean distances recorded for the U19 and O19 players may be reflective of a higher playing intensity at this level of competition when compared with the domestic players. This may possibly be related to the representative players being required to maintain a higher match intensity and perform more repeated, short-intensity movements, such as sprinting and change of direction, throughout match-play when compared with the domestic players.

Similar with previous studies (6,9,18), there were differences in the physical demands between positional groups. The GK and WD had the lowest mean PL, suggesting lower overall physical demands of match-play for these positions. This is similar to previous studies (6,18) where GK had the lowest mean PL, but they also reported GS as having the lowest PL, which was not the case in the current study. When examined by the different levels of participation, the position with the lowest PL also varied. The U19 WD and GS had the lowest mean PL, whereas the domestic and O19 GK and WD players recorded the lowest mean PL. The finding that GK had the lowest mean PL may be related to rule-imposed limitations whereby this position is allowed in one-third of the court only (6), thereby limiting the space in which this position is able to move and accumulate distance. This may also be reflected in the mean PL for the WA and WD where there are similar rule-imposed limitations (6), whereas C, which has the least rule-imposed limitations and is involved within both attacking and defensive play (19), had the highest mean PL overall. Again, this varied by participation level, with O19 GD recording the highest mean PL. Further research is warranted in exploring the different levels of match participation, especially at the representative levels of competition to enable further analysis to be undertaken.

Although C recorded a greater activity profile at the domestic level of participation, GA recorded a greater activity at the O19 level. These findings conflict with previous studies (6,7,22), reporting C as having a higher PL than other playing positions while GA had a lower activity profile. As shown in Table 2, GA had a higher mean PL, 2DPL, PL_F, PL_S, and PL_V when compared with C. Because of the specific tactical requirements undertaken, it is possible that this finding may be unique to this playing position at this level of competition. Although C recorded a higher mean distance at the O19 level, the difference in PL may be related to a higher number of short-burst high-intensity activities, such as accelerating, decelerating, change-of-direction, and jumping undertaken by GA that resulted in a lower mean distance but a higher mean PL.

In contrast to previous findings that identified a greater relative vertical contribution in shooters, centers, and defenders of a higher-playing standard (9), no differences were found between the relative contribution of the vertical component

to overall PL (domestic: 69% vertical contribution; U19: 68% vertical contribution; and O19: 68% vertical contribution). Although no differences were noted in the relative contributions, it is important to note that O19 players attained the highest PL, and consequently, the overall contribution of PL_F, PL_S, and PL_V within this group was higher than that of the domestic players. Although no practical differences were identified within this study, practitioners can use individual PL vectors to examine the specific movement patterns or tactical performance attributes that may contribute to variation of individual PL vectors and, therefore, the overall PL value. Such information can be used to devise individual player- and position-specific training programs that prepare players for the specific demands of competition while also reducing the impact of excessive physical exertion to facilitate safer engagement within netball.

The current study followed 3 levels of participation, but there were only a limited number of representative (U19 and O19) matches recorded. Although this is more than some (6,7), but not all (22), previous studies reporting on the accelerometer-based physical demands of netball players, the differences recorded may be related to the number of matches each level participated in. Consequently, the results reported should be interpreted with caution and may not be transferable to other levels of netball participation.

The results identify the unique physical and physiological profiles of individual netball positional groups and between levels of competition. Given the high physical demands of netball and, therefore, the potential for injury, individual player- and position-specific training programs are required to develop players for the specific demands of competition while also reducing the impact of excessive physical exertion to facilitate safer engagement within netball. Further, the identification of the differing physical and physiological profiles of individual positional groups highlights the importance of integrating microtechnology into the routine monitoring of intermittent court-based sports, such as netball.

Practical Applications

The findings of this study can be used to assist with training and tactical strategies that are used in match environments. The present findings suggest that there are specialized playing positions within netball that have unique movement and physiological demands. The C is required to undertake large loads, travel long distances, and requires a higher aerobic capacity. Training for this position should focus on the development of the aerobic capacity for both attack and defending roles. The GK and GS undertake lower distances and have a lower aerobic capacity. Training for these positions should focus more on skill development and the development of anaerobic capacities. The WA, WD, GD, and GA are comparable across a variety of performance and movement characteristics. Training for these positions should focus on skill development and the physiological capacity to interchange between these positions.

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