Physical Profiles of All-rounders, Batters, and Bowlers in Sub-Elite Women's Cricket

Jolandi Jacobs, Benita Olivier, Corlia Brandt, Gandhi Jafta

ABSTRACT

The unique physical profile of each player's role in sub-elite women's cricket is vital for optimising performance as these players progress to the elite levels. This quantitative, cross-sectional study investigates the physical profiles of sub-elite women's cricket players as a group and compares these profiles across different player roles. Sub-elite female cricket players in the (hidden for peer review) women's cricket league were included in this study. A battery of physical assessments were conducted at the start of the 2022/23 season. The physical assessments included body composition, individual muscle strength testing using dynamometry, 2km time trial, countermovement jump (CMJ), single leg jump (SLJ), intermitted mid-thigh pull (IMTP), push-up (PU) and hop test (HT) on force plates. A total of 44 female players (20.86 ± 1.6) were included in the study. Differences were found in muscle mass ($p=0.004$) and peak power ($p=0.040$) for all-rounders and bowlers. Player roles presented with different dominant ($p=0.006$) and non-dominant ($p=0.066$) knee flexion strength. The bowlers' body composition and physical profile are compromised compared to batters and all-rounders. There were several physical strength and power differences between pace and spin bowlers in CMJ and SLJ tests for jump height ($p=0.009$) and peak power ($p=0.006$). Batters performed the best in the 2km time trial. Body composition and musculoskeletal profiles for each player role can be baseline markers in sub-elite women's cricket. Stakeholders can use this information to guide physical preparation for players advancing to elite levels.

Keywords: Physical preparation, female cricket, team sport, musculoskeletal screening, muscle strength, pre-season

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INTRODUCTION

Women's cricket is drastically rising in participation and professionalism across the globe. The interest in women's cricket has also lured the sports science and medicine community in recent years (7,11). Sports science and medicine researchers in cricket investigate musculoskeletal health with physical preparation, performance enhancement and injury prevention outcomes. The musculoskeletal system plays a crucial role in cricket, particularly in batting, bowling, and fielding. It enables athletes to make rapid changes in direction, accelerate, and maintain power and stability during gameplay. There is evidence to suggest that several physical factors, including body composition and muscle strength, have a significant impact on cricket performance (2,33). Therefore, prioritising the physical preparation of cricket players is crucial to achieve optimal performance.

It is essential to understand the physical profile of players to develop physical preparation guidelines in cricket. Physical preparation guidelines are widely researched in men's cricket (32), including physical profiling for individual player roles such as bowlers and batters (8). The same is not evident for women's cricket as current research supporting physical preparation for female cricket players focuses on female players as a group (18) or explores the profiles of elite pace bowlers (11,12,26). Letter et al. (11) found that faster female pace bowlers possess superior physical characteristics, such as maximal upper body muscle strength, compared to slower pace bowlers. However, there was no difference in CMJ height among the faster and slower female pace bowlers (11). Letter et al. (12) found changes in physical profiles between different age groups but no changes for seasonal assessments. Letter et al. (11) suggested that improving lower body strength, anaerobic capacities, and upper body pulling strength may enhance performance in female pace bowlers. Murphy et al. (18) found a dominant arm internal rotation:external rotation strength deficit ratio in female cricket players and linked this with a 1.79 times increased risk of shoulder injury.

Differences exist between the physical profiles and demands among various player roles (8,32). Identifying individual shortcomings and tailoring approaches to the sub-roles in cricket is crucial, considering each player's diverse demands and physical capacities (32). The lack of existing research on the physical profiles of female cricket players, particularly those besides pace bowlers, is apparent. This dearth of information highlights the shortcomings of current sports science and medicine approaches in women's cricket. Extrapolating research findings from men's cricket and elite female pace bowlers to all female cricket players raises valid concerns. Comprehensive findings regarding the different player roles (32) would be vital for developing and informing strength and conditioning principles to enhance the physical preparation of the female cricket player. Various physical parameters such as body composition, muscle strength, and aerobic fitness must be evaluated to investigate the differences between individual player roles.

Physical profiles of batters, wicketkeepers and all-rounders in women's cricket are unexplored, and highlight a significant gap in the current literature.. Moreover, there is a noticeable lack of research for sub-elite female cricket players. Therefore, the primary objective of this study was to investigate the physical profiles of sub-elite female cricket players. The secondary aim was to examine the differences in physical profiles between the different player roles. This study will provide practitioners in the field with baseline data to assess the physical characteristics of batters, pace bowlers, spin bowlers, and all-rounders. These comparisons can facilitate the identification of strengths and weaknesses for each player role, thereby enabling the optimisation of goals within their existing physical preparation programs.

METHODS

Experimental approach to the problem

A descriptive cross-sectional study was conducted on a cohort of sub-elite female cricket players. This study aimed to establish baseline values for the physical profiles of sub-elite female cricket players and compare the physical profiles across various player roles to assist the physical preparation for this cohort. The players were classified into three primary categories: batters, bowlers, and all-rounders. A further sub-analysis was performed on pace and spin bowlers. A standard performance test battery was selected to assess the physical profile of each player, and it consisted of body composition, physical strength, and aerobic fitness tests. The study was undertaken two weeks before the commencement of the 2022/2023 cricket season. Testing was done at the respective cricket unions' facilities and on two separate days. For the first testing day, players were assessed using a body composition test, isolated isometric strength assessments with a dynamometer and functional performance tests using force plates. On the second testing day, an aerobic fitness test was conducted.

Subjects

The authors invited sub-elite female cricket players in the (hidden for peer review) domestic women's league to participate in the study. The study included only players who were injury free on the day of testing, and testing was conducted two weeks before the commencement of the 2022/23 season. Three teams were selected to participate in the study, with 44 female cricket players who willingly participated. All participants (including guardians of 18-year-olds and younger) gave their written informed consent for their data to be used in the study. Ethical approval to conduct this study was obtained from (hidden for peer review), and permission was obtained to invite contracted players (hidden for peer review).

Procedures

The testing procedures were conducted on two separate days for each participant. On both days of testing, players were instructed to wear comfortable athletic attire and to warm up and stretch in their own accustomed way before testing. After warming up, the players were instructed to rest for 10 minutes before testing started. All testing procedures are summarised in the supplementary document (Suppl. Table S1). On the first day, body composition and individual and functional strength tests were performed. There were 30 seconds of recovery time allowed between each trial of each test and five minutes of recovery time before advancing to a new testing procedure. On the second testing day, the individuals were asked to run a 2km time trial (2km TT) for aerobic fitness. One primary tester was responsible for instructing and capturing the tests, with support from trained assistants. The primary tester underwent extensive training in dynamometry and force plate testing with VALD software (VALD Performance, QLD, Australia). The primary tester did all the force plates and dynamometry instruction and capturing. The assistants were trained to capture the body compositions and assisted with capturing the 2km TT data.

Player characteristics

Players were classified as batters, bowlers or all-rounders by their coaches and according to the Cricket Consensus Statement (19). A batter is a player who predominantly bats and is not required to bowl or keep wickets for most of the innings. An all-rounder is a bowler who regularly bowls at least 10% of a team's overs and bats in the top seven batting positions for most of the innings. Bowlers are classified as pace or spin bowlers. A wicketkeeper stands close to the stumps when keeping for slow bowlers and positions further from the stumps for fast bowlers (19).

Body composition

The body composition measurements were obtained utilising an Omron (Model OM-BF511) body composition scale (Omron BF306, Omron Healthcare, Inc., Vernon Hills, IL). There is good agreement between Omron and skinfolds measurements (bias = 0.2 ± 3.0%, $p = 0.76$) (6) and between Omron and Dual-energy X-ray absorptiometry (DEXA) (13). Body weight, body mass index (BMI), body fat percentage (BF%), muscle mass percentage (MM%) and resting metabolic rate (RMR) were all recorded for analysis.

Isolated muscle strength tests

Isometric muscle strength of the upper and lower extremities was assessed using a handheld dynamometer (DynaMo, VALD Performance, QLD, Australia). Participants were instructed to perform maximum voluntary contractions for three seconds for identified groups, including external shoulder rotators, internal shoulder rotators, quadriceps, hamstrings, and gluteus maximus muscles. Concurrent validity for isometric muscle strength testing with a dynamometer compared to Cybex showed fair to excellent concurrent validity for the shoulder external rotators, knee flexors, knee extensors and hip extensors (5). All muscle strength testing was conducted in the mid-range of the specific joint. The shoulder tests were performed with the player at 30° shoulder abduction, 30° scaption, 30° diagonal and 90° elbow flexion (21) and using the DynaMo testing belts (indirect isometric resistance) for standardised testing procedures. The lower leg muscle strength test was performed using the direct application of the dynamometry with the player in a prone position (9). To standardise the measurements, the same testing individual who conducted the dynamometry tests was used to test all the players in all of the teams. The trial was immediately terminated if the tester detected compensatory movements, such as moving the humerus into shoulder abduction when external rotation was required or excessive lumbar extension during hip extension testing. The player was then requested to perform the test again without compensatory movements to standardise testing. A thirty-second rest period (11,12) was allowed between each trial, including any incorrect trials. Each muscle group was tested three times, with the average value of the three tests recorded for data analysis.

Functional muscle strength tests

All functional muscle strength tests were done according to VALD ForceDecks protocols (Suppl. Table S1). All tests conducted on the force plates were captured, cleaned, and analysed using VALD ForceDecks software (VALD, ForceDecks, Brisbane, Australia). Jump testing using the force plates involved participants starting at a normal mean force (N). The countermovement jump test (CMJ), single leg jump test (SLJ) and hop test (HT) were used to determine lower body muscle strength and power. The isometric mid-thigh pull (IMTP) and a velocity push-up were used to assess upper-body muscle strength and power. Variables such as jump height, peak force, peak power, velocity at take-off and power are all reliable coefficients of variation (CV < 10%) (23). Inter-rater coefficients of variation are less than 0.6% for the SLJ, indicating good reliability for these tests (16). Studies have indicated good inter-rater and intra-rater reliability for the IMTP test (14). The instructions for the jump test were to ‘jump as high as you can’ and for the strength test to ‘push as hard as you can into the force plates’. For all the jump tests, no arm swing was allowed. Each player had one testing trial for each test, with the tester correcting the player as needed. The testing trial was not recorded. After that, each participant’s body weight was recorded to normalise the data per body weight. Players were asked to perform three max trials for each test (CMJ, SLJ, HT, and IMTP). For the CMJ, SLJ and IMTP participants were asked to do a single repetition and were allowed 30 seconds of recovery time before another repetition was done (11,12). Players were allowed five minutes of rest before advancing to a new testing procedure (30). The average value of the three tests was recorded. For the hop test, players had one trial of continuous jumps. Players were requested to 'jump as high as possible for ten consecutive jumps'. The average peak force of five tests from a single testing trial was used for data analysis.

Aerobic fitness test

On a separate day from the body composition and strength testing, the players' aerobic capacity was determined by completing a 2km TT. Time trials have good re-test reliability (10). The players were instructed to run a 2km time trial wearing their trainers around the boundary line of a cricket field. The 2km TT distance was measured beforehand for standardisation of the test. Only one trial of the 2km TT was captured for analysis.

Statistical analysis:

All the data from the force decks, muscle strength tests, aerobic test, and body compositions were exported to Microsoft Excel (Microsoft 365, Microsoft Corporation, Washington, USA). For accurate analysis of left- and right-handers, we used the terms "dominant" and "non-dominant" when referring to either the left or right sides. Data were displayed as overall means and standard deviations for all variables. Further analyses investigated discrepancies between sub-groups, namely batters, bowlers (pace and spin) and all-rounders. Should the test have dominant and non-dominant variables, additional analyses were done to investigate whether the measurements differed for all participants. Analyses were done using either the t-test, Kolmogorov-Smirnov (KS), or Kruskal Wallis (KW) test. In all statistical tests conducted, the Shapiro-Wilk test was used for normality. We then compared the results of the batters, bowlers, and all-rounders using Analysis of Variance (ANOVA) or the KS test, depending on adherence to ANOVA assumptions (normality, equal variance and independence). This was followed by testing for differences between pace and spin bowlers using the t-test or KS test, depending on the data distribution. The effect sizes were calculated using Cohen's d, omega squared and eta-squared. All statistical analyses were performed using R (version 4.2.2) and R Studio (version 2023.3.0.386) software (29).

RESULTS

Player characteristics

A total of 44 female participants with a mean age of 20.86 ± 1.60 years participated in the study. Players (n=44) were divided into subgroups for further analysis: batters (n=15), bowlers (n=15) and all-rounders (n=14). The bowlers were sub-divided into pace (n=19) and spin bowlers (n=9). There was one left-handed bowler and two left-handed batters.

Body composition

The body composition for each player role is indicated in Table 1. The total means for body composition can be seen in Supplementary Table S2. All-rounders had the highest overall body weight, BMI and MM% compared to other player roles. Bowlers had the lowest body weight and MM% compared to the other body roles. There was lower MM% (p=0.019, ES=0.18) and RMR (p=0.004, ES=0.23) for bowlers compared to all-rounders. Body composition analysis between pace and spin bowlers showed no major differences.

Isolated muscle strength tests

Isolated muscle strength of the upper and lower limbs of all player roles can be seen in Table 1. All-rounders had increased strength of dominant and non-dominant internal rotators (IR) and shoulder external rotators (ER) compared to batters and bowlers. Batters had increased rotational shoulder dominant and non-dominant strength compared to bowlers. Bowlers had the lowest overall muscle strength for both upper and lower muscle strength compared to batters and all-rounders. There were differences in shoulder IR for spin bowlers (p=0.013) and knee flexion for both pace (p=0.001) and spin bowlers (p=0.014). All-rounders had increased knee flexion, knee extension, hip extension, and muscle strength compared to batters and bowlers. Batters had the highest knee extension strength compared to all-rounders and batters. There were differences when implementing the KS test in dominant knee flexion for all the player roles.

Functional muscle strength tests

Functional muscle strength tests for all player roles can be seen in Table 1. The total means for functional muscle strength tests can be seen in Supplementary Table S2. Analysis of the CMJ test indicated a difference (p=0.04, ES=0.11) in peak power for all-rounders compared to other player roles. For comparisons of CMJ between pace and spin bowlers, there were differences in jump height (p=0.009, ES=1.24) and peak power normalised with body weight (p=0.006, ES=0.88). Analysis of the SLJ test indicated no significant differences between the dominant and non-dominant sides for all player roles. Further analysis of the SLJ demonstrated a difference in peak power (p=0.038, ES=0.34) of the non-dominant leg for batters compared to other player roles. There was a difference during the SLJ for non-dominant leg jump height (p=0.042, ES=0.86) for pace compared to spin bowlers. For the hop test, the all-rounder had the highest peak power and batter the highest jump height compared to other player roles (Table 1).

Pace bowlers had higher jump height, mean landing Rate of Force Development (RFD) and peak power than spin bowlers. There were no differences among any player roles for the hop test. Analysis of the IMTP indicated increased force generation for the entire test duration to be higher for the all-rounder than other player roles. There were no other differences among the player roles for the IMTP test. Analysis of the push-up test indicated differences between dominant (p=0.001) and non-dominant sides for concentric mean force for all the players. Bowlers had the highest concentric mean power compared to other player roles. Pace bowlers had higher concentric mean force on the dominant side than spin bowlers, but there was no difference between pace and spin bowlers.

Table 1. Group means, SD and p-value for body composition and musculoskeletal testing for sub-elite female cricket players per player role

Variables	All-rounder	Batter	Bowler	P-value	Effect sizes	Pace Bowler	Spin Bowler	P-value	Effect sizes
Body composition									
Weight [kg]	70.14 ± 11.91	65.9 ± 9.0	62.09 ± 9.03	0.113[a]	0.10[z]	65.03 ± 10.37	66.75 ± 12.67	0.716	0.15[x]
BMI [kg/m^2]	24.27 ± 3.75	23.17 ± 3.2	23.17 ± 3.18	0.596[a]	0.02[z]	23.04 ± 3.03	24.27 ± 3.6	0.370	0.37[x]
Body Fat [%]	31.05 ± 7.27	31.07 ± 7.83	34.23 ± 5.59	0.365[a]	0.05[z]	31.54 ± 5.83	34.24 ± 7.94	0.358	0.39[x]
Muscle mass [%]	30.51 ± 3.32	29.5 ± 3.7	26.98 ± 3.08	0.019[a]	0.18[z]	29.12 ± 3.37	28.05 ± 4.31	0.507	0.28[x]
RMR [kcal]	1477.87 ± 111.03	1403.79 ± 104.46	1336.2 ± 114.01	0.004[a]	0.23[z]	1403.63 ±117.54	1400 ± 162.45	0.951	0.03[x]
Isolated muscle strength tests									
Shoulder IR (D) [N]	84.07 ± 33.62	71.79 ± 37.73	69.87 ± 24.19	0.465[b]	0.01[y]	74.05 ± 30.03	76.56 ± 25.61	0.814[c]	0.09[x]
Shoulder IR (ND) [N]	87.64 ± 31.39	74.86 ± 41.98	70.8 ± 20.31	0.163[b]	0.04[y]	74.05 ± 26.41	86.78 ± 28.7	0.342[c]	0.46[x]
Shoulder ER (D) [N]	69.21 ± 22.04	68.86 ± 32.27	63.73 ± 14.77	0.702[b]	0.03[y]	62.26 ± 15.31	74.00 ± 23.52	0.255[c]	0.59[x]
Shoulder ER (ND) [N]	70.14 ± 21.66	66.14 ± 27.15	63.67 ± 13.08	0.541[b]	0.02[y]	63.42 ± 13.92	72.44 ± 24.06	0.319	0.45[x]
Knee Flexion (D) [N]	205.87 ± 26.83	160 ± 32.51	170.73 ± 48.6	0.006[b]	0.20[y]	186.05 ± 42.53	186.80 ± 42.68	0.965	0.02[x]
Knee Flexion (ND) [N]	172.4 ± 27.77	140.79 ± 34.48	157.4 ± 36.41	0.066[b]	0.08[y]	161.05 ± 29.16	165.20 ± 34.23	0.749	0.12[x]
Knee Extension (D) [N]	230.27 ± 40.67	227.21 ± 93.86	197.33 ± 44.07	0.118[b]	0.05[y]	209.05 ± 48.16	217.20 ± 38.05	0.623	0.18[x]
Knee Extension (ND) [N]	217.47 ± 34.3	236.86 ± 116.61	201.87 ± 28.51	0.438[b]	0.01[y]	202.16 ± 32.00	221.70 ± 30.23	0.121	0.63[x]
Hip Extension (D) [N]	240.53 ± 57.15	224.14 ± 77.81	219.33 ± 46.21	0.419[b]	0.01[y]	236.26 ± 55.59	214.70 ± 46.25	0.279	0.42[x]
Hip Extension (ND) [N]	248.4 ± 41.77	218 ± 53.82	228.07 ± 69.34	0.289[b]	0.01[y]	246.74 ± 54.16	224.10 ± 65.19	0.361	0.38[x]

Internal rotation (IR), external rotation (ER), dominant (D), non-dominant (ND), body mass index (BMI), resting metabolic rate (RMR), rate of force development (RFD), countermovement jump (CMJ), single leg jump (SLJ), hop test (HT), time trial (TT), newton (N)

P-value classifications: [a]ANOVA [b]Kruskal Wallis test [c]Kolmogorov (all other statistical tests were done using t-test).

Effect size classifications: [x]Cohen's d [y]Kruskal Wallis (Eta squared) [z]ANOVA (Omega squared)

Variables	All-rounder	Batter	Bowler	P-value	Effect sizes	Pace Bowler	Spin Bowler	P-value	Effect sizes
Functional strength tests									
CMJ									
Jump Height [cm]	22.89 ± 4.85	23.52 ± 3.82	23.53 ± 2.85	0.880[a]	0.77[z]	24.54 ± 2.93	20.20 ± 4.01	0.009	1.24[x]
Peak Power [W]	2873.73 ± 64.70	2705.43 ± 389.14	2391.53 ± 479.78	0.040[b]	0.11[y]	2657.32 ± 640.52	2478.20 ± 512.16	0.585[c]	0.31[x]
Peak Power/ BM [W/kg]	41.73 ± 8.22	40.96 ± 3.39	38.44 ± 3.22	0.171[b]	0.03[y]	41.53 ± 7.20	36.78 ± 2.53	0.006[c]	0.88[x]
Peak Landing Force [N]	2848.07 ± 642.85	2925.21 ± 516.13	2839.93 ± 786.94	0.930[a]	0.86[z]	2703.42± 631.63	2962.90 ± 711.93	0.346	0.39[x]
SLJ									
Concentric Mean Force (ND) [N]	933.27 ± 163.42	928.14 ± 150.55	833.00 ± 117.22	0.118[a]	0.08[z]	879.00 ± 154.20	873.50 ± 142.14	0.924	0.04[x]
Eccentric Mean Force ND) [N]	716.13 ± 168.67	677.00 ± 123.43	611.00 ± 93.48	0.102[a]	0.12[z]	641.0 ± 105.48	693.30 ± 202.07	0.853[c]	0.32[x]
Jump Height (Flight Time) (ND) [cm]	10.47 ± 2.77	11.414 ± 2.43	11.20 ± 1.65	0.518[a]	0.80[z]	11.49 ± 2.14	9.63 ± 2.19	0.042	0.86[x]
Peak Power (ND) [W]	1634.07 ± 369.89	1730.93 ± 375.39	1414.20 ± 224.11	0.038[a]	0.34[z]	1545.74 ± 311.13	1461.60 ± 356.61	0.537	0.25[x]
Peak Power / BM (ND) [W/kg]	23.39 ± 4.78	26.24 ± 4.85	22.90 ± 2.44	0.079[a]	0.19[z]	23.77 ± 2.61	22.120 ± 5.40	0.381	0.39[x]
Peak Landing Force (ND) [N]	2261.4 ± 518.35	2166.43 ± 291.92	1966.47 ± 251.03	0.102[a]	0.12[z]	2156.63 ± 513.14	2021.10 ± 216.55	0.555[c]	0.34[x]
Concentric Mean Force (D) [N]	923.33 ± 171.26	905.14 ± 143.36	828.27 ± 123.77	0.187[a]	0.09[z]	871.00 ± 159.99	864.20 ± 144.30	0.909	0.04[x]
Eccentric Mean Force (D) [N]	711.20 ± 155.57	658.14 ± 105.04	611.67 ± 92.43	0.092[a]	0.15[z]	641.16 ± 106.11	686.60 ± 181.98	0.836[c]	0.31[x]
Jump Height (Flight Time) (D) [cm]	10.04 ± 3.07	11.11 ± 3.32	11.92 ± 2.03	0.206[a]	0.13[z]	11.63 ± 2.44	9.49 ± 2.83	0.059	0.81[x]
Peak Power (D) [W]	1573.60 ± 424.11	1544.79 ± 256.19	1510.07 ± 269.18	0.868[a]	1.63[z]	1559.95 ± 354.35	1438.10 ± 280.54	0.849[c]	0.38[x]
Peak Power / BM (D) [W/kg]	21.22 ± 8.01	23.59 ± 4.02	24.47 ± 3.11	0.260[a]	0.25[z]	24.02 ± 3.72	20.15 ± 9.08	0.225	0.56[x]
Peak Landing Force (D) [N]	2225.73 ± 38.06	2157.14 ± 407.14	2040.93 ± 87.13	0.556[a]	0.88[z]	2165.95 ± 96.20	2032.50 ± 220.83	0.668[c]	0.30[x]

Internal rotation (IR), external rotation (ER), dominant (D), non-dominant (ND), body mass index (BMI), resting metabolic rate (RMR), rate of force development (RFD), countermovement jump (CMJ), single leg jump (SLJ), hop test (HT), time trial (TT), newton (N)
P-value classifications: [a]ANOVA [b]Kruskal Wallis test [c]Kolmogorov (all other statistical tests were done using t-test).
Effect size classifications: [x]Cohen's d [y]Kruskal Wallis (Eta squared) [z]ANOVA (Omega squared)

Variables	All-rounder	Batter	Bowler	P-value	Effect sizes	Pace Bowler	Spin Bowler	P-value	Effect sizes
Hop test									
Mean Active Stiffness [N/m]	24359.65 ± 8882.18	32685.31 ± 34177.79	22248.36 ± 6264.3	0.971[b]	0.05[y]	23253.5 ± 6775.3	25042.3 ± 8232.4	0.582	0.24[x]
Mean Jump Height (Flight Time)[cm]	22.53 ± 10.72	23.58 ± 5.1	22.72 ± 5.58	0.273[b]	0.15[y]	23.52 ± 9.15	20.83 ± 7.37	0.239[c]	0.32[x]
Mean Landing RFD [N/s]	37658.07 ± 13844.38	41906.21 ± 26658.12	36965.67 ± 8229.79	0.996[b]	0.05[y]	38872.7 ± 10551.8	35813.5 ± 12233.7	0.512	0.27[x]
Mean Peak Power [W]	6581.24 ± 7478.77	4830.42 ± 1422.85	4414.15 ± 1358.96	0.662[b]	0.03[y]	5929.62± 6688.92	4831.1 ± 1776.76	0.910[c]	0.22[x]
IMTP									
Force at 50ms [N]	947.79 ± 151.81	860.07 ± 207.53	803.37 ± 277.37	0.219[a]	0.03[z]	862.03 ± 266.94	881.56 ± 167.4	0.729[c]	0.09[x]
Force at 100ms [N]	1001.21 ± 154.65	937.00 ± 286.88	914.00 ± 216.15	0.567[a]	0.02[z]	954.11 ± 209.05	946.67 ± 164.86	0.920	0.04[x]
Force at 150ms [N]	1058.00 ± 167.40	973.36 ± 262.56	975.27 ± 217.93	0.509[a]	0.01[z]	1000.74 ± 216.56	1027.56 ± 159.05	0.716	0.14[x]
Force at 200ms [N]	1115.79 ± 182.19	1024.00 ± 271.11	1038.60 ± 233.6	0.534[a]	0.02[z]	1052.16 ± 230.07	1099.56 ± 163.48	0.539	0.24[x]
Peak Vertical Force [N]	1517.57 ± 336.28	1349.71 ± 242.96	1395.40 ± 296.99	0.307[a]	0.01[z]	1393.68 ± 298.02	1531.56 ± 331.75	0.307	0.44[x]
Push up test									
Concentric Mean Power / BM [W/kg]	3.13 ± 0.46	3.30 ± 0.49	2.68 ± 0.41	0.111[a]	0.06[z]	2.86 ± 0.66	2.94 ± 0.85	0.824	0.10[x]
Concentric Mean Velocity [m/s]	0.46 ± 227.43	0.49 ± 220.00	0.41 ± 208.88	0.135[a]	0.05[z]	0.43 ± 0.09	0.44 ± 0.12	0.809	0.11[x]
Eccentric Mean Power / BM [W/kg]	2.56 ± 0.60	3.00 ± 0.94	2.52 ± 0.73	0.245[a]	0.02[z]	2.50 ± 0.73	2.63 ± 0.55	0.635	0.19[x]
Concentric Mean Force (ND) [N]	227.43 ± 0.73	220.00 ± 0.98	208.88 ± 0.60	0.372[a]	0.01[z]	217.87 ± 35.74	212.58 ± 26.79	0.577[c]	0.17[x]
Concentric Mean Force (D) [N]	254.54 ± 41.83	226.68 ± 30.85	213.46 ± 26.36	0.010[a]	0.18[z]	235.13 ± 39.83	225.49 ± 43.25	0.409[c]	0.23[x]
Aerobic fitness test									
2km TT [min]	11:02 ± 1:37	10:32 ± 1:28	11:14 ± 1:28	0.467[a]	0.04[z]	10:57 ± 1:19	11:05 ± 1:31	0.539[c]	0.10[x]

Internal rotation (IR), external rotation (ER), dominant (D), non-dominant (ND), body mass index (BMI), resting metabolic rate (RMR), rate of force development (RFD), countermovement jump (CMJ), single leg jump (SLJ), hop test (HT), time trial (TT), newton (N)

P-value classifications: [a]ANOVA [b]Kruskal Wallis test [c]Kolmogorov (all other statistical tests were done using t-test).

Effect size classifications: [x]Cohen's d [y]Kruskal Wallis (Eta squared) [z]ANOVA (Omega squared)

Aerobic fitness test

The group means of the 2km TT results for each player role are displayed in Supplementary Table S2. Batters had the lowest 2km TT times, followed by all-rounders and bowlers. There were no differences between the player roles. Further statistical analysis indicated no difference between pace and spin bowlers.

DISCUSSION

Our study found differences between the physical profiles and demands among various player roles in women's cricket owing to the distinct physical and technical capabilities demanded by each role. The investigation into the anthropometrics demonstrated that female cricket players presented with a BMI of 23.55 ± 3.35 kg/m^2, which is within the healthy weight category compared to other studies on body composition in female athletes (1,17,31). The body weight of sub-elite female cricket players in this study (66.05 ±10.59) was comparable to that of elite female cricket players (8,18,25). Our study found that all-rounders presented with the highest body weight, BMI and MM%, whereas bowlers presented the lowest body weight, RMR and MM%. These findings were similar to elite men's cricket, where bowlers presented with lower body weight than batters (32). Bowlers in our study presented with the highest BF% and batters with the lowest BF%. The overall body fat percentage reported in our study (32.14 ± 6.95) was higher than in other female sports (1). The body composition of players is expected to vary depending on their specific player roles in cricket (8,32). Cricket coaches, sports science and medicine staff should consider implementing individualised training and nutritional strategies to optimise body composition in each player role, thereby supporting their performance and overall health.

The aerobic fitness test showed superior performance by batters, followed by all-rounders and bowlers. The aerobic fitness results in our study for the sub-elite female cricket players present with overall slower time compared to the elite female cricket players (11). Letter et al. (12) found that faster female pace bowlers are superior in all anaerobic capacity measures. It could be indicative that female pace bowlers are outperformed by batters as they might have more aerobic capacity compared to the anaerobic capacity of fast bowlers (11). Our study observed that female batters had lower BF%

compared to the bowlers, which aligns with the findings of the aerobic fitness test. Further research is needed to examine the aerobic fitness of players at the sub-elite level and determine the rationale behind the higher aerobic fitness observed in the female batters in our study.

Our study employed shoulder strength tests, push-up tests, and the IMTP to assess upper body strength. All-rounders demonstrated superior shoulder strength, IMTP and push-up results compared to other player roles. All-rounders presented with the biggest deficit in dominant IR/ER shoulder strength compared to other player roles. Dominant shoulder IR/ER deficit is linked to a risk of shoulder injury in elite female cricket players (18). Applied practitioners should aim for an IR:ER ratio to reduce the risk of dominant-side shoulder injury by maintaining a 1:1 ratio, specifically in the all-rounder cohort. Interestingly, batters and all-rounders had increased IR/ER shoulder strength in the non-dominant compared to the dominant shoulder. Future research should investigate the effect of increased shoulder IR/ER shoulder strength on technical performance during batting. Sports science and medicine practitioners should also address these IR/ER deficits and increase overall shoulder strength by implementing shoulder strength and conditioning programs. Another interesting finding in our study is that bowlers presented with the weakest IR/ER shoulder strength compared to other player roles. One potential explanation for the comparatively lower shoulder strength observed in bowlers, as compared to batters and all-rounders, may be attributed to the repetitive and high-intensity nature of the bowling action. It is possible that bowlers might be more susceptible to shoulder injuries, leading to a reduction in shoulder strength over time. This is just a speculative explanation, and the actual reasons would require further investigation. Previous studies have found a correlation between shoulder extensor strength and ball release speed among sub-elite male pace bowlers (4). Applied practitioners should focus on the current physical preparation of female pace bowlers to enhance their overall muscle strength in the shoulder for improved performance in pace bowling. Additional research is necessary to investigate the relationship between shoulder strength and bowling performance in female pace bowlers.

For lower body strength testing, our study found increased dominant knee flexion strength compared to the non-dominant side for all player roles. Stakeholders in women's cricket should consider implementing strength and conditioning programmes to enhance hamstring muscle strength as a collective effort to reduce the disparity between dominant and non-dominant sides. Further research is needed to investigate this deficit and the effect of hamstring strength on female cricket players' performance. Subsequent examinations of various player roles revealed that all-rounders exhibited higher peak power in the CMJ and hop tests in comparison to other player roles. Additionally, all-rounders exhibited greater muscle strength in knee flexion and hip extension than batters and bowlers. The scarcity of research on the physical attributes of all-rounders poses challenges in comparing our study's results to existing literature. It could be suggested that all-rounders dedicate more time to technical and physical development due to the multifaceted nature of their role, in contrast to individuals who solely focus on bowling or batting. The increase in training volume could result in increased muscle strength, power, MM% and overall body weight, as seen in the results.

In our study, batters outperformed the bowlers in the CMJ. This finding is also evident in elite men's cricket (32). Batters also presented with higher muscle strength and muscle mass compared to bowlers. A notable discovery was that batters exhibited the greatest non-dominant knee extension strength. Investigations for the batters only revealed that the non-dominant leg exhibited greater peak power, concentric force, and jump height than the dominant leg. Batters showed the most significant deficit in knee flexion/extension ratio compared to other player roles. Batters are expected to exhibit greater knee flexion angles and more repetitive knee flexion-to-extension motions during batting (27). In addition to the distinctions above, it is noteworthy that batters exhibited the shortest 2km TT time, followed by all-rounders and bowlers.

An evident finding of this study was that bowlers had the lowest overall upper and lower muscle strength compared to all-rounders and batters. Further investigations suggest that spin bowlers have higher IMTP peak force than pace bowlers. Interestingly, pace and spin bowlers performed equally in the push test, whereas pace bowlers performed better than the spin bowlers in men's cricket (32). The physical demands and biomechanics also differ between spin and pace bowlers as, spin bowlers rely on muscles responsible for producing rotational movements (22,24). This could result in increased focus on enhancing leg strength as part of their physical preparation (15), leading to higher IMTP scores than pace bowlers, as seen in this study. Pace and spin bowlers strongly emphasise their bowling skills, which demand technique over physical strength. In contrast, all-rounders and batters rely on muscular strength for powerful shots, resulting in boundaries (28). Their higher IMTP scores demonstrate that batters and all-rounders may prioritise physical preparation over bowlers to develop upper and lower body strength.

Pace bowlers in our study presented with increased jump height and peak power compared to spin bowlers. Further testing identified a big difference in the non-dominant and dominant leg jump heights during the SLJ for pace bowlers compared to spin bowlers. This finding is also evident in other research comparing male pace and spin bowlers (32). Pace bowlers also presented with higher jump height and peak power than spin bowlers. There were differences in non-dominant leg jump height in pace bowlers compared to spin bowlers, which could be attributed to the bowling biomechanics of pace bowlers. Pace bowlers had reduced knee extension strength but increased hip extension strength compared to spin bowlers. In male fast bowling, bowlers typically aim for minimal knee flexion at front foot contact, as a braced knee is advantageous for ball release speed (20). However, researchers have found that females have different bowling biomechanics with a rotational pelvis and trunk rotation technique similar to throwing to generate momentum (3). The pace bowlers in our study present with increased hip strength and reduced knee extension strength. This physical profile fits into the available research suggesting that female pace bowlers use techniques and muscles other than knee bracing to increase ball release speed. However, this is just speculation, and further research is needed to examine the muscles and biomechanics used by female pace bowlers.

This study offers important insights into the physical profiles of sub-elite women's cricket players, but some limitations must be acknowledged. The study sample was limited to a specific geographical area and a small cohort, potentially impacting the generalisability of the findings to other sub-elite female cricket populations. The study's cross-sectional design hinders the establishment of cause-effect relationships between musculoskeletal profiles and performance outcomes. The IMTP results were not normalised to body weight and may influence the results of the study. We suggest that future researchers investigate shoulder strength testing in end ranges to explore the effects of eccentric muscle strength at longer muscle lengths. Also, future research should explore alternative assessments, such as an open kinetic chain test without end-range deceleration, like a medicine ball throw, to expand the scope of research for female cricket players.

This study portrays semi-elite female cricket players' body composition and physical profile for all player roles. The study aimed to bridge the knowledge gap in women's cricket by providing valuable insights into their physical characteristics and potential areas for strength and conditioning. Our findings indicate a dominant and non-dominant knee flexion strength deficit across all player roles. Moreover, evidence suggests that sub-elite all-rounders exhibit greater muscle strength, power, body weight, and muscle mass than bowlers. Bowlers displayed lower muscle strength and body and muscle mass yet demonstrated higher jump heights than other player roles. Batters showed superior aerobic fitness capacity relative to other player roles. Considering the unique musculoskeletal profiles of each player role in sub-elite women's cricket is crucial for optimising performance as these players progress to the elite levels.

Practical Applications

The findings of this study presents physical differences between different player roles in women's cricket. The benchmark values from this study will enable applied sports science practitioners to guide physical preparation programs for individual player roles. Applied practitioners should pay special attention to the physical profile of bowlers (pace and spin) as they present with reduced individual muscle group strength and functional muscle strength compared to other player roles. Also, body compositions for sub-elite pace and spin bowlers are compromised compared to batters and all-rounders. Bowlers should be given special consideration to increase muscle mass and strength, including the collaboration of the dietitian and strength and conditioning coach. For all player roles, hamstring muscle strength is significantly reduced in the non-dominant leg. Current physical preparation programs should aim to increase hamstring strength and close the deficit between the dominant and non-dominant sides. Batters as a group present with the lowest hamstring muscle strength compared to bowlers and all-rounders. All-rounders present with dominant shoulder IR/ER ratio deficit, predisposing them to shoulder injury. Practitioners should aim to increase the IR:ER ratio to 1:1 to reduce injury risk for all player roles, specifically for all-rounders.

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Appendix A

Supplementary data to this article can be found in Appendix A.

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