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ORIGINAL RESEARCH REPORT

Normative Standards for Isokinetic and Anthropometric Classifications of University-Level Netball Players

Kyra-Kezzia Duvenage,[1] Yolandi Willemse,[1] Hans de Ridder,[2] and Mark Kramer[2]
[1]Centre for Health and Human Performance, North-West University, Potchefstroom, South Africa; [2]Physical Activity, Sport, and Recreation (PhASRec) Research Focus Area, North-West University, Potchefstroom, South Africa

Context: The purpose of the study was to develop normative ranges and standards for knee and shoulder isokinetic and anthropometric values. These standards can be qualitatively interpreted and allow practitioners to classify isokinetic and anthropometric values more objectively for university-level netball players. ***Design:*** Posttest only observational study design. All players were only evaluated once during the in-season to generate normative ranges. ***Methods:*** A total of 51 female players volunteered. Participants were evaluated on an isokinetic dynamometer at 60° per second to obtain knee-extensor and knee-flexor values as well as shoulder-flexor and shoulder-extensor values. A total of 16 anthropometric variables were collected including stature, body mass, 8 skinfolds, and 6 circumferences. Between-group differences were calculated to determine whether playing level was a differentiating factor in data. ***Results:*** Normative standards were developed for isokinetic parameters associated with the knee and shoulder joints as well as skinfolds and circumference measures. No statistically significant between-group differences were evident ($\chi^2_{\text{Kruskal–Wallis}}[2] = 3.96$, $P = .140$). ***Conclusion:*** These standards can be used by coaches and practitioners to set attainable goals for individual players or those from secondary leagues, classify individual and team-based performances, and facilitate decision-making processes.

Keywords: body fat, concentric, eccentric, kinanthropometry, strength

Key Points

- Normative standards for isokinetic strength and anthropometry in high-level female netball players are provided.
- These norms allow for both within- and between-sport comparisons to classify performance requirements more objectively.
- The benchmarks can be used by coaches and practitioners to set attainable goals and facilitate decision-making processes.

Netball is a sport with high incidence rates of injury, particularly to the ankle and knee joints, which account for a large proportion (ie, 8%–84%) of all injuries.[1,2] Injuries to the upper body are also reported but are less common in the literature, typically accounting for ∼4% to 54% of all netball injuries.[1] Although netball is played by both sexes, it is a sport predominantly played by females as evidenced by the netball literature showing that females represent 89.5% to 94.3% of hospitalizations and 81% to 98% of injuries.[1] Despite the known risk factors for injury development, including lower-limb asymmetry,[1,3] chronic ankle instability,[4] and poor balance, agility, and core stability,[5–7] conclusive evidence for links between netball-specific qualities and injury risk is conflicting. Furthermore, despite the knowledge of effective injury prevention strategies (eg, adequate neuromuscular, plyometric, and strength training),[8] the incidence rates of certain injuries (eg, anterior cruciate ligament and shoulder) have not decreased appreciably in the past 2 decades.[9,10]

In this context, the development of normative standards for physical qualities (eg, lower- and upper-body strength) and risk factors in netball is necessary to optimize performance and reduce the risk of injury. Isokinetic dynamometry is a widely used method for objectively measuring muscle strength[11] and is highly relevant to netball performance which is reliant on high levels of strength particularly in the knee and shoulder joints for successful execution of skills such as jumping, landing, and throwing.[12] However, normative standards for isokinetic knee and shoulder strength in uninjured netball players have not been emphatically established, making it difficult to accurately identify individuals with suboptimal strength levels and develop targeted interventions to improve strength and reduce injury risk.[7,13]

Previous research has identified physical qualities such as body fat percentage and somatotype (ie, endomorphy) as contributing factors to injury risk, but the extent to which these factors apply to netball is not definitive.[7,12,14] Moreover, the variability in anthropometric measurements (eg, skinfolds, circumferences, height, body mass index, and muscle mass) and expected normative ranges in uninjured players has not been fully explored, particularly in terms of what constitutes extremely low or high values.[7,13–15] Knowledge of anthropometric parameters within the context of netball is of considerable importance for determining (1) player position suitability (eg, goal shooters may benefit from being taller; wing attack might benefit from agility and speed which are dependent, at least to some extent, on muscle mass), (2) performance enhancement (eg, whether a conditioning program enhances lean muscle mass), (3) injury prevention, and (4) general health and

Duvenage https://orcid.org/0000-0001-5444-4385
Willemse https://orcid.org/0000-0003-3486-6745
de Ridder https://orcid.org/0000-0001-8766-8916
Kramer (Mark.kramer@nwu.ac.za) is corresponding author, https://orcid.org/0000-0003-2237-7549

conditioning (eg, changes in body fat and lean mass throughout a season or due to injury).[12,15]

Given that optimal netball performance requires high levels of strength, agility, and change of direction ability,[5] it is important to quantify individual performances and identify those with subpar levels in order to implement mitigating strategies to increase the performance of the squad as a whole. Additionally, given the increasing player loads and match schedules in recent years, the ability to judiciously intervene and correct physical disparities is more important than ever.[16,17]

The purpose of the present study is therefore 3-fold: (1) to develop objective normative standards for isokinetic knee and shoulder strength, (2) to develop objective normative standards for anthropometric parameters, and (3) to evaluate between-group differences for isometric and anthropometric parameters in female netball players. By addressing these gaps in knowledge and developing normative standards for physical qualities, we aim to better understand and inform the development of targeted strategies to optimize performance and potentially reduce the risk of injury.

Methods

Participants

A total of 51 university-level netball players volunteered for the study (age: 20.22 [1.70] y; stature: 1.76 [0.07] m; body mass: 72.89 [9.03] kg). An a priori sample of 50 was proposed for the generation of cohort-specific normative data sets.[18] All players provided written informed consent prior to data collection which was approved by the institutional review board and conformed to the World Medical Association's Declaration of Helsinki. Players were evaluated during the middle portion of the in-season phase of their training cycle and were free of injury at the time of testing. Inclusion criteria consisted of the following: must be female, aged 18–26 years, participate competitively at the university level for a minimum of 1 year, and a minimum of 3 years netball playing experience. Participants would be excluded under the following circumstances: presence of injury, cardiovascular and respiratory problems, pregnancy, recent surgery (<6 mo), and recent illness (eg, influenza). Participants were also provided with clear instructions prior to testing: arrive at testing at least 3 hours postprandial and in a hydrated state, avoid consumption of caffeine and alcohol for at least 12 hours, and avoid strenuous exercise for at least 24 hours.

Anthropometry

A total of 16 anthropometric measurements were captured per participant (stature, body mass, 8 skinfolds, and 6 girths), with all measurements being taken early in the morning prior to breakfast and before training. All measurements were taken twice with the mean value being retained for analysis. All skinfolds were measured to the nearest 0.1 cm on the player's dominant side (Harpenden, Baty International) at 8 anatomical sites, namely the triceps, biceps, subscapular, iliac crest, supraspinale, abdominal, thigh, and calf.[19] Circumferences were measured to the nearest 0.1 cm using a flexible steel tape (Cescorf Equipment) at 6 different sites, namely relaxed upper arm, flexed upper arm, forearm, wrist, mid-thigh, and calf.[19] The intratester technical error of measurement scores for the present study was 5.75% and 1.14% for skinfolds and girths, respectively, which fall well within the acceptable limits.[20] From the skinfold and circumference measures, the body fat percentage[21] and estimated muscle mass[22] could be calculated.

Isokinetic Strength Tests

The concentric strength of the knee extensors and flexors as well as shoulder extensors and flexors was evaluated using an isokinetic dynamometer at a speed of 60^o per second (Cybex II, Humac Norm, CSMi).[11] Prior to testing of the knee, all participants completed a 5-minute cycle on a stationary cycle ergometer at low intensity (ie, 75 W) followed by joint-specific dynamic stretches. The warm-up routine for the shoulder evaluation consisted of submaximal rowing on a rowing ergometer for 2 minutes followed by joint-specific dynamic stretching.[11,23] Each participant was positioned on the dynamometer according to the requirements for joint-specific testing[11] and allowed to complete the familiarization protocol prior to the formal evaluation. The familiarization protocol entailed submaximal torque production across 5 repetitions with each subsequent repetition requiring proportionately greater torque outputs (eg, 50%, 70%, 80%, 90%, and 100% effort). The formal evaluation for each joint consisted of 5 maximal efforts at a velocity of 60° per second, whereby participants were instructed to push as hard and fast as possible through the full range of motion. Participants were provided with 2 minutes of recovery between limbs and 5 minutes between joints.[11] The order of limb testing was not randomized but was noted for replication purposes.

Statistical Analyses

All data were evaluated for normality using the Shapiro–Wilk test, where deviations from normality were accepted at $P < .05$. Data are shown as mean (SD) unless otherwise stated. For the first and second objectives, the creation of benchmarks was achieved by evaluating Z-score performance bands which were allocated qualitative descriptions as follows: <–3.0 (extremely low); >–3.0 to ≤–2.0 (very low); >–2.0 to ≤–1.0 (low); >–1.0 to ≤–0.5 (below average); >–0.5 to ≤0.5 (average); >0.5 to 1.0 (above average); >1.0 to ≤2.0 (high); >2.0 to ≤3.0 (very high); and >3.0 (extremely high). The Z-scores were then converted back to the raw scores such that the standards can be presented in original units. For the third objective, between-group differences were evaluated using the analysis of covariance with age, percentage body fat, and estimated muscle mass serving as covariates in the model. Omega-squared (ω^2) was used as a measure of the effect size, the magnitude of which was interpreted as the following: very small: <0.01; small: 0.01 to 0.06; medium: 0.06 to 0.14; and large: >0.14.[24] Should the model yield significant between-group differences, the Holm correction served as the post hoc adjustment for multiple between-group comparisons. All statistical analyses were completed using the R programming language.[25,26]

Results

An example of participant-specific performances for dominant and nondominant knee-extensor torques coupled with the normative standard rating is shown in Figure 1. Detailed normative ranges for each parameter related to isokinetic *knee* and *shoulder* strength are shown in Tables 1–2. Normative data for *skinfold* measurements are shown in Table 3, and normative data for *circumference* measurements are shown in Table 4.

Between-group differences (ie, club vs provincial vs national) for knee-extensor and shoulder torques are shown in Figure 2. Data are shown separately for the dominant (panels 2A and 2C) and nondominant (panels 2B and 2D) limbs, respectively. Although marginal between-group differences are present, these did not reach

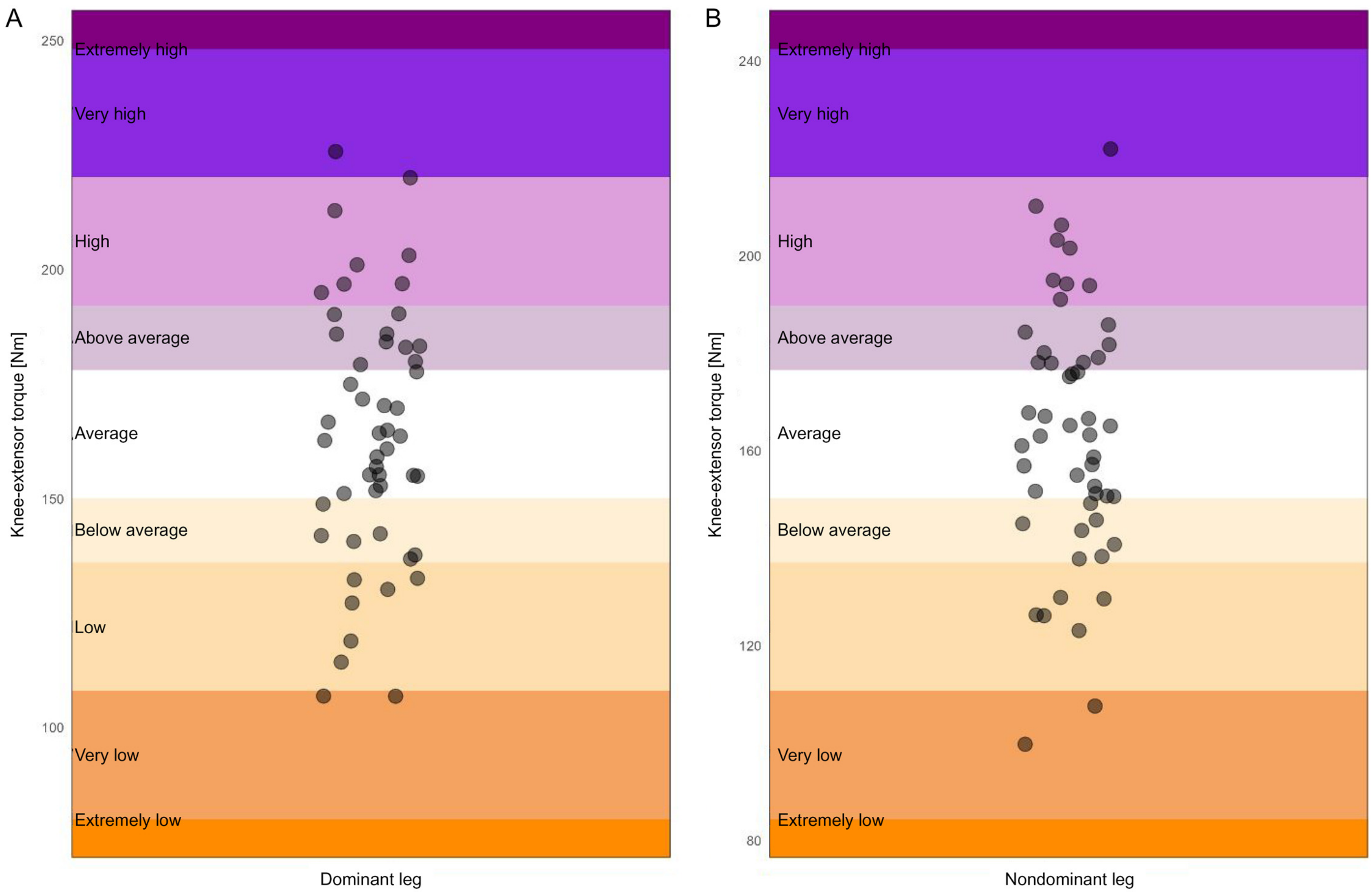

Figure 1 — Example classification scheme for individual participants. Individual data points are shown for the dominant leg (panel A) and the nondominant leg (panel B), where the performance of each participant is classified according to the normative data generated.

Table 1 Normative Data for Knee Isokinetic Strength

	Low			Average			High		
Knee joint	Extremely low	Very low	Low	Below average	Average	Above average	High	Very high	Extremely high
Extensor Dom PT, N·m	<107	107–114	114–131	131–145.5	145.5–159	159–175	175–185	185–196	>196
Extensor Dom % BM	<140	140–152	152–188	188–206	206–221	221–235	235–251.5	251.5–265	>265
Flexors Dom PT, N·m	<11	11–75	75–85	85–92.5	92.5–102	102–113	113–123	123–127	>127
Flexors Dom % BM	<98	98–104	104–116	116–128	128–143	143–155	155–167	167–188	>188
H:Q ratio Dom, %	<47	47—50	50–55.5	55.5–59	59–64	64–68	68–73.5	73.5–77.5	>77.5
Extensor ND PT, N·m	<100	100–123	123–130	130–144.5	144.5–155	155–167	167–181	181–196	>196
Extensor ND % BM	<143	143–146	146–171.5	171.5–192.5	192.5–215	215–232	232–245.5	245.5–280	>280
Flexors ND PT, N·m	<79	79–80	80–88.5	88.5–95	95–103	103–115	115–122	122–132.5	>132.5
Flexors ND % BM	<98	98–110	110–120.5	120.5–132.5	132.5–143	143–155	155–168.5	168.5–179	>179
H:Q Ratio ND, %	<49	49–53	53–55.5	55.5–61	61–65	65–68	68–73.5	73.5–79.5	>79.5
Extensor-deficit ND vs Dom	<1	1–1	1–1	1–3	3–6	6–10	10–13	13–19	>19
Flexor-deficit ND vs Dom	<1	1–2	2–3	3–4	4–7	7–10	10–13.5	13.5–17	>17

Abbreviations: BM, body mass; Dom, dominant; H:Q, hamstring-to-quadricep ratio; ND, nondominant; PT, peak torque.

Table 2 Normative Data for Shoulder Isokinetic Strength

	Low			Average			High		
Shoulder	Extremely low	Very low	Low	Below average	Average	Above average	High	Very high	Extremely high
Extensor Dom PT, N·m	<41	41–52	52–53.5	53.5–56	56–60	60–64	64–69	69–73	>73
Extensor Dom %BM	<63	63–69	69–72	72–77	77–83	83–89	89–95	95–99.5	>99.5
Flexor Dom PT, N·m	<23	23–28	28–36	36–39	39–43	43–46	46–49	49–50	>50
Flexor Dom %BM	<27	27–45	45–51	51–54	54–60	60–63	63–66	66–75	>75
Flex:Ext ratio Dom, %	<40	40–52	52–55	55–64	64–67	67–72	72–78.5	78.5–83.5	>83.5
Extensor ND PT, N·m	<39	39–47	47–52	52–54	54–57	57–61	61–65	65–71	>71
Extensor ND %BM	<60	60–69	69–70.5	70.5–75	75–80	80–86	86–89	89–95	>95
Flexor ND PT, N·m	<28	28–33	33–34.5	34.5–38	38–41	41–46	46–49	49–50	>50
Flexor ND %BM	<33	33–45	45–49.5	49.5–52.5	52.5–57	57–60	60–67.5	67.5–72	>72
Flex:Ext ratio ND, %	<50	50–53	53–59.5	59.5–62.5	62.5–70	70–76	76–79.5	79.5–85	>85
Extensor-deficit ND vs Dom	<0	0–0	0–2	2–3.5	3.5–6	6–9	9–12.5	12.5–18	>18
Flexor-deficit ND vs Dom	<0	0–0	0–0	0–3	3–8	8–11	11–15.5	15.5–20	>20

Abbreviations: BM, body mass; Dom, dominant; Ext, extensor; Flex, flexor; ND, nondominant; PT, peak torque.

statistical significance. The analysis of covariance results for between-group comparison for all *isokinetic* parameters can be viewed in Supplementary File SF1, and all *anthropometric* parameters in Supplementary File SF2 [available online]). No between-group differences (ie, club vs provincial vs national) were evident for any of the parameters associated with isokinetic strength (all $P > .085$) nor the parameters associated with anthropometry (all $P > .193$).

Discussion

The aim of the present study was to provide normative data and performance standards for isokinetic knee and shoulder parameters, as well as anthropometric parameters for university-level netball players. Additionally, we evaluated whether between-group differences (ie, level of play) were present for each of the measured parameters.

Fundamental performance components of netball include jumping, landing, cutting, and pivoting for which adequate strength of the knee joint musculature is crucial.[12] The development of normative standards for isokinetic knee strength would allow coaches and trainers to identify potential imbalances or weaknesses in a player's knee strength and develop targeted training programs to address these issues. A factor that is often overlooked when assessing performance in high-level teams pertains to the *variability* in performance, whereby players can accomplish similar levels of on-field functioning despite a wide range in strength and/or anthropometric qualities. Furthermore, normative standards allow for more direct performance comparisons across teams at different levels (ie, national vs international) or across different sporting codes (eg, handball vs soccer). The results of the present study showed that, for example, the average peak knee-extensor and knee-flexor torques of university-level netball players were similar to those of elite female *handball* players,[27] indicating the similar physiological and biomechanical demands of the 2 sports. Within the context of the present standards, the knee-extensor torques of professional female soccer players would be classified as *extremely high*, whereas the knee-flexor torques would be classified as *above average* relative to the cohort in the present study.[28] Similarly, adequate shoulder strength is vital, given that throwing, passing, and shooting movements are used extensively in netball. The cohort of the present study compared favorably, although somewhat less, in terms of shoulder strength when contrasted against elite athletes from other overhead sports such as handball, basketball, and volleyball.[29] Developing normative standards for shoulder strength would contribute to the more objective assessment of throwing and shooting abilities by enabling coaches and trainers to identify potential areas of weakness. When the shoulder norms generated in the present study are used to classify performances of elite overhead athletes across other sports such as handball and volleyball, the strength of the latter athletes would be classified as *very high/extremely high* in terms of peak toques but *average* in terms of flexion/extension ratios.[29] Furthermore, with the development of normative standards for key anthropometric measures, such as height, weight, body fat percentage, and/or limb lengths, it is possible to identify any areas where athletes may have an advantage or disadvantage on the court. Such information can be used to develop programs focused on improving specific aspects of a player's physical attributes, such as agility, speed, and endurance, to enhance their performance on the court.[7,15,30]

A key aspect of the present study pertains to the *range* of expected values within a highly competitive university-level netball squad. With this in mind, we opted to classify standards from *extremely low* to *extremely high*[31,32] rather than *very poor* to *excellent*.[33] The latter format suggests that exceptionally low values are "inferior," whereas these values merely capture the variability within a squad or playing level. The latter is important given that sporting performance is positively affected by perceptions of confidence[34]; therefore, providing ratings that may be interpreted as overtly negative may be counterproductive.

The normative standards presented in our study can therefore be used to set attainable goals for individual athletes or secondary leagues by knowing the objective standards for specific classifications and levels of performance. It is however important to note that our data may facilitate interpretation provided that similar cohorts (eg, age, gender, and mass), and data acquisition procedures are utilized. Whether performance benchmarks, as presented here, could be used for talent identification purposes or initial screening for placement in a squad would require further research.

Table 3 Normative Data for Body Skinfolds

	Low			Average			High		
	Extremely low	Very low	Low	Below average	Average	Above average	High	Very high	Extremely high
Biceps Dom, %	<3.2	3.2–4.2	4.2–5.03	5.03–6.1	6.1–6.8	6.8–8.1	8.1–10.95	10.95–12.92	>12.92
Biceps ND, %	<4.2	4.2–4.7	4.7–5.77	5.77–7.25	7.25–9.4	9.4–11.2	11.2–12.95	12.95–16.18	>16.18
Triceps Dom, %	<8	8–10	10–11.2	11.2–14.2	14.2–15.47	15.47–19.1	19.1–22.92	22.92–23.67	>23.67
Triceps ND, %	<8.9	8.9–10.1	10.1–11.1	11.1–13.17	13.17–15.2	15.2–17.3	17.3–19.77	19.77–22.13	>22.13
Subscapular Dom, %	<6.4	6.4–7	7–7.72	7.72–8.47	8.47–9.5	9.5–11.07	11.07–13.42	13.42–17.1	>17.1
Subscapular ND, %	<6.4	6.4–7.1	7.1–8	8–8.6	8.6–9.27	9.27–11.53	11.53–14.05	14.05–17.47	>17.47
Iliac crest Dom, %	<8.6	8.6–9.4	9.4–10.9	10.9–13.78	13.78–16.07	16.07–19.13	19.13–23.13	23.13–24.7	>24.7
Iliac crest ND, %	<9.0	9–11	11–11.9	11.9–13.08	13.08–14.53	14.53–18.07	18.07–23.35	23.35–26	>26
Supraspinale Dom, %	<5.8	5.8–7.1	7.1–7.92	7.92–9.4	9.4–11	11–13.6	13.6–16.45	16.45–20.42	>20.42
Supraspinale ND, %	<4.7	4.7–6.6	6.6–7.1	7.1–8.83	8.83–10	10–12.8	12.8–15.92	15.92–18.8	>18.8
Abdominal Dom, %	<7.8	7.8–11	11–12.32	12.32–14.07	14.07–15.6	15.6–19.15	19.15–22.5	22.5–24.47	>24.47
Abdominal ND, %	<9.3	9.3–11.4	11.4–12.05	12.05–13.53	13.53–14.47	14.47–18	18–21.53	21.53–24	>24
Front thigh Dom, %	<12.0	12–13.9	13.9–18.76	18.76–20.75	20.75–22.4	22.4–27.47	27.47–31.1	31.1–37.7	>37.7
Front thigh ND, %	<12.4	12.4–13.2	13.2–18.15	18.15–21.32	21.32–23.9	23.9–27.67	27.67–32.2	32.2–36.93	>36.93
Medial calf Dom, %	<6.2	6.2–9	9–11.9	11.9–13	13–15.65	15.65–18.3	18.3–20.67	20.67–22.2	>22.2
Medial calf ND, %	<6.13	6.13–7.4	7.4–11.1	11.1–13.77	13.77–15.9	15.9–19	19–20.9	20.9–23.05	>23.05
Body fat, %	<14.7	14.7–14.9	14.9 – 17.0	17.0–18.8	18.8–20.6	20.6–22.3	22.3–25.4	25.4–27.6	>27.6
Estimated muscle mass, kg	<27.5	27.5–29.9	29.9–32.6	32.6–34.2	34.2–37.1	37.1–39.3	39.3–40.9	40.9–43.5	>43.5

Abbreviations: Dom, dominant; ND, nondominant.

Table 4 Normative Data for Circumferences

	Low			Average			High		
	Extremely low	Very low	Low	Below average	Average	Above average	High	Very high	Extremely high
Relaxed upper arm girth Dom	<24.55	24.55–25	25–25.93	25.93–26.85	26.85–27.5	27.5–28.3	28.3–29.6	29.6–32.6	>32.6
Relaxed upper arm girth ND	<24.4	24.4–24.4	24.4–25.7	25.7–26.6	26.6–27.5	27.5–28.55	28.55–29.45	29.45–32.5	>32.5
Flexed upper arm girth DOM	<26.1	26.1–26.5	26.5–27.7	27.7–28.2	28.2–28.75	28.75–29.75	29.75–30.53	30.53–33.25	>33.25
Flexed upper arm girth ND	<25.15	25.15–26.45	26.45–26.93	26.93–27.4	27.4–28.4	28.4–29.55	29.55–30.3	30.3–32.69	>32.69
Forearm girth Dom	<21.8	21.8–23.45	23.45–23.62	23.62–24.23	24.23–24.6	24.6–25.65	25.65–26.25	26.25–26.73	>26.73
Forearm girth ND	<21.2	21.2–23	23–23.43	23.43–23.8	23.8–24.3	24.3–25.1	25.1–25.9	25.9–26.38	>26.38
Wrist girth Dom	<14.3	14.3–14.9	14.9–15	15–15.25	15.25–15.55	15.55–16	16–16.28	16.28–16.75	>16.75
Wrist girth ND	<14.55	14.55–14.65	14.65–15	15–15.23	15.23–15.55	15.55–16	16–16.23	16.23–16.83	>16.83
Mid-Thigh girth Dom	<48.8	48.8–51.85	51.85–52.55	52.55–53.95	53.95–55	55–57.8	57.8–59.25	59.25–61.24	>61.24
Mid-Thigh girth ND	<49.15	49.15–50.8	50.8–51.93	51.93–53.19	53.19–54.53	54.53–57.75	57.75–59.08	59.08–60.83	>60.83
Calf girth Dom	<33.1	33.1–34.1	34.1–35.4	35.4–36	36–38.55	38.55–39.55	39.55–40.55	40.55–41.19	>41.19
Calf girth ND	<33.1	33.1–34.4	34.4–35.4	35.4–36.35	36.35–38	38–39.15	39.15–40.58	40.58–41.25	>41.25

Abbreviations: Dom, dominant; ND, nondominant. All data are presented in centimeters as the unit of measure.

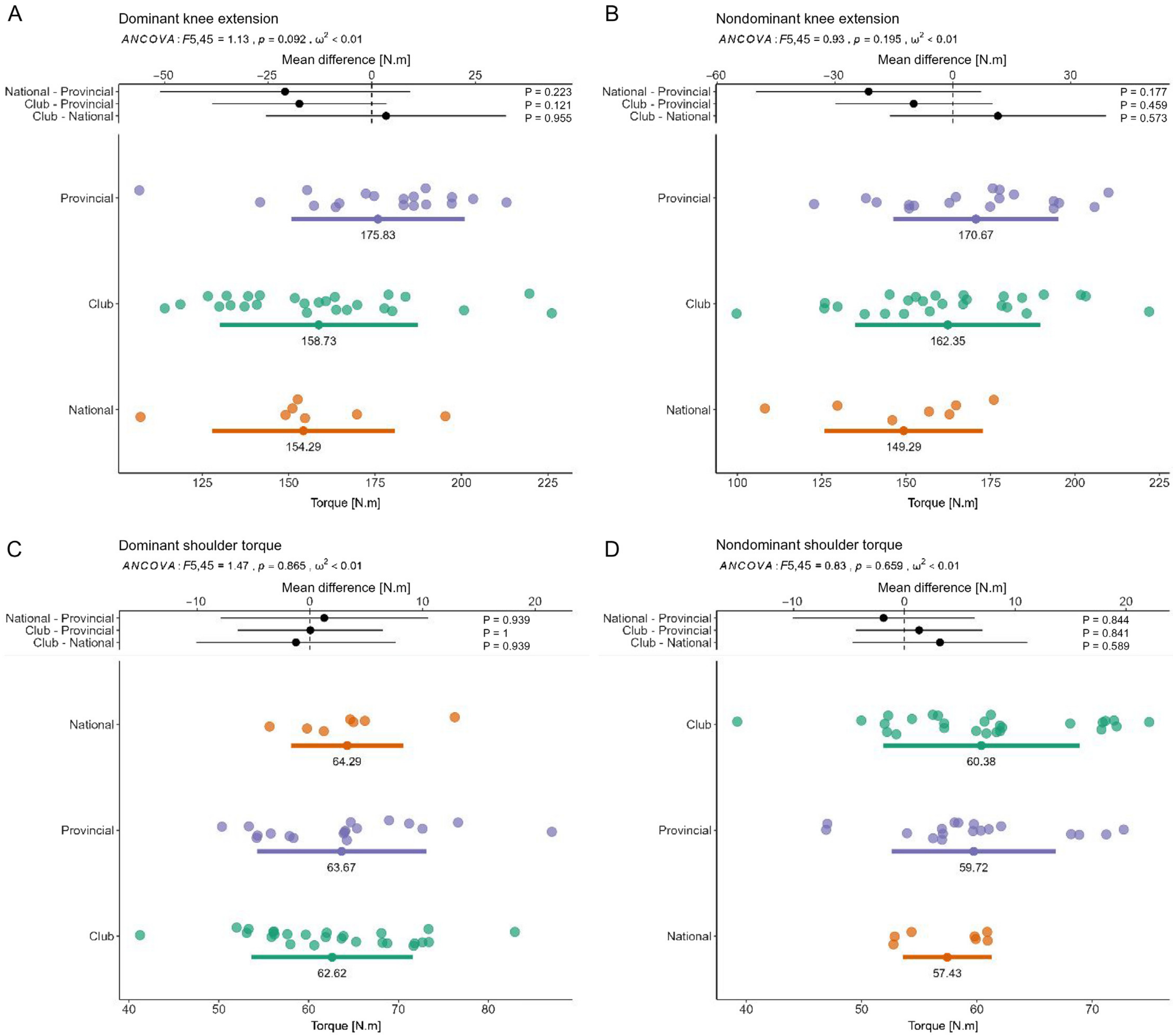

Figure 2 — ANCOVA results for between-group differences regarding knee and shoulder torques. Panel A refers to the dominant leg, panel B refers to the nondominant leg, panel C refers to dominant shoulder, and panel D refers to nondominant shoulder. Note: The overall statistical results of the ANCOVA are shown at the top of each panel. The mean between-group differences and the Holm-corrected *P* values are shown at the top portion of each panel (black horizontal lines are mean ± 95% CI). The individual data points for each group are shown in the bottom portion of each panel together with the mean (SD; thick, solid horizontal lines). ANCOVA indicates analysis of covariance.

Given that potential differences in isokinetic strength and anthropometric values may exist for netball athletes at different playing levels (eg, club, provincial, and national levels), we investigated whether apparent differences were present between groups within the same squad. The latter is important since it is typically expected that those athletes competing more regularly at the *club* level may have lower isokinetic strength values than athletes at higher levels due to a lack of access to high-quality training programs, coaching, and sports medicine services. At the *provincial* level, netball athletes are expected to be more advanced since they have access to better training programs, coaching, and sports medicine services. This may lead to higher isokinetic strength values and more favorable anthropometric profiles compared to club-level athletes since provincial-level athletes often undergo more regular testing and screening to identify any weaknesses or imbalances in their strength and develop targeted training programs to address these areas.[7] At the *national* level, netball athletes are typically classified as elite and tend to have been selected based on their exceptional skill level and physical abilities. National-level athletes are expected to have higher isokinetic strength values and a more optimal anthropometric profile compared to club- and provincial-level athletes due to the high level of competition and demands of international play. These athletes usually undergo frequent testing and screening to monitor their progress and identify areas for improvement in their strength and overall performance. Despite such anticipated differences, our results showed that there was a lack of evidence for differences in playing level within a heterogeneous squad for all parameters evaluated, indicating that similar exposure to training likely reduces potential differences related to the level of play. However, further research is necessary to determine whether this finding holds true across different squads and/or other overhead sports such as basketball, volleyball, or handball (see Figure 2). The current results would seem to suggest that once a given level of performance is attained, comparable strength and/or anthropometric metrics are evident across similar sports. This could potentially imply that further improvements in these metrics are unlikely to elicit further performance enhancements, which may infer that time should be spent on the development of other qualities such as technical and tactical skills.

It is worth mentioning certain limitations to the present standard thresholds should be considered. The data were collected during the *in-season* phase of training on the basis that it represents the period when players are at peak levels of performance and therefore exemplifies the target parameters needed during competition. It is known that condition and performance change throughout a training season, and the benchmark standards should therefore be interpreted within context.[15–17] Additionally, the player profile within a team may vary by season, which could have implications for the mean squad performance. Therefore, benchmarks should be periodically updated to reflect the changing dynamics of squads and/or leagues. Intriguingly, Bruce et al[17] showed that teams capable of maintaining a similar profile over consecutive years (including coaching and support staff) are likely to incur greater successes. Finally, we did not control for the phases of the menstrual cycle as the testing dates were controlled by the coaching and conditioning staff and were therefore beyond the control of the research team.

Based on the information provided, we recommend that the normative data and performance categories offered in the tables may be used to facilitate decision-making processes by practitioners. These norms should however not be interpreted in isolation but rather in conjunction with multiple parameters to provide a holistic picture of player performances, capacities, and capabilities. Future research should incorporate additional joints (eg, hip and ankle), additional planes of motion (eg, frontal and transverse planes), and injury data to determine whether norms may identify at-risk players and whether such norms can be used in return-to-play decision making.

Conclusions

In conclusion, the present study provides valuable normative data and performance standards for isokinetic knee and shoulder, and anthropometric parameters specific to university-level netball players. These benchmarks can be used by coaches and practitioners to set attainable goals for individual athletes or secondary leagues and to facilitate decision-making processes. However, it is important to consider certain caveats, such as the changing dynamics of squads and the need to periodically update standards, and to interpret the benchmarks within context. Overall, these norms should be used in conjunction with multiple parameters to provide a holistic picture of player performances, capacities, and capabilities.

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