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Percentile Rank Data for the Countermovement Vertical Jump Measured by a Jump-and-Reach Device in Law Enforcement Recruits

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Abstract

The countermovement vertical jump (VJ) has been used to indirectly measure the lower-body power of law enforcement recruits. Different methods can be adopted to measure the VJ; there is limited research that has published normative data for the VJ measured with a jump-and-reach device as performed by recruits. This study calculated normative percentile rank data for VJ height and peak anaerobic power measured in watts (PAPw) derived from the VJ for law enforcement recruits. Retrospective analysis on 833 recruits (683 men, 150 women) from one agency was conducted. Recruits completed the VJ as part of a battery of fitness assessments prior to their training academy. Jump height was recorded and used to derive percentile rankings for all recruits, men, and women, in the following bands: 90-100, 80-89, 70-79, etc. Jump height was also used to calculate PAPw, and percentile rankings for this variable were derived. All recruits, men, and women, had a mean VJ height of 52.63±11.59, 55.34±10.16, and 40.33±9.54 cm, respectively. For PAPw, the means for all recruits, men, and women, were 4756.07±1088.23, 5072.49±877.87, and 3315.33±732.54 watts, respectively. The data indicated the male recruits tended to perform better than female recruits; 74% of all women were in the bottom three percentile bands for VJ height, and 93% of women were in the bottom three bands for PAPw. Female recruits will likely need specific strength and power training prior to and during academy. The provision of normative VJ data provide recruit benchmarking and could inform fitness program design for staff.

Keywords: First Responder, Lower-Body Power, Normative Data, Peak Anaerobic Power, Police, Tactical

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Introduction

Law enforcement personnel have a need for lower-body power in their occupation. For practitioners who work with and train law enforcement personnel, it is important that they have a method for measuring this particular fitness domain. Lower-body power is often extrapolated from performance in different jump assessments (McGuigan, 2015). Jump assessments are easy to administer and provide a valid metric of an individual's capacity, even if they do not provide a direct measure of power (Burr et al., 2007). The absolute measure of jump height or distance is often used as the metric for lower-body power; the greater the jump height or distance, the more powerful the individual. Jump height has been critiqued as an interpretation for lower-body power (Morin et al., 2019). Although jump height may not always be the most optimal lower-body power interpretation, it still has its place in law enforcement testing. Officers may need to clear fences and obstacles in their occupation, and often will be assessed on their ability to perform these types of tasks. For example, 6-foot walls have been used in exit occupational exams for law enforcement recruits (Lockie et al., 2022a; Lockie et al., 2021; Lockie et al., 2020d). An obstacle such as a wall not change its height relative to the power produced by individual, so absolute jump performance is relevant (Lockie et al., 2022b). Nonetheless, power can be calculated from jump performance (Sayers et al., 1999).

The countermovement vertical jump (VJ) is a common assessment used to measure lower-body power in law enforcement personnel (Lockie et al., 2018b). Numerous studies have shown the value of the VJ in law enforcement testing. For example, police recruits who reported an injury or illness during their training academy had a lower VJ height compared to recruits who did not (injured/non-injured: 42.03 ± 7.35 centimeters [cm] vs. 44.00 ± 7.56 cm; illness/no illness: 41.88 ± 7.48 cm vs. 44.44 ± 7.47 cm) (Orr et al., 2016). Moreover, Orr et al. (2016) stated that recruits with the lowest VJ heights were more than three times as likely to suffer injury and/or illness when compared to those with the highest VJ heights. Other studies have demonstrated that recruits who graduate academies tend to have a better VJ performance than those who do not successfully complete academy requirements (Dawes et al., 2019b; Lockie et al., 2020a). Better VJ displacement related to a faster 5-meter (m), 10-m, and 20-m sprint in Special Weapons and Tactics officers (r = -0.572 to -0.608) (Dawes et al., 2015). Moreno et al. (2019) detailed significant correlations between VJ height (r = 0.209) and VJ peak power (r = 0.568) with a 74.84-kilogram (kg) body drag velocity over 9.75 m in law enforcement recruits. When performed by male and female civilians, Moreno et al. (2024) found a significant relationship between VJ height and 74.84-kg body drag time (r = -0.356). Peak anaerobic power measured in watts (PAPw) derived from the VJ related to 74.84-kg and 90.72-kg body drag times (r = -0.465 to -0.668). Lockie et al. (2021) found that a better VJ related to faster completion of a 99-yard obstacle course (r = -0.35), 6-foot chain link fence climb (r = -0.25), 6-foot solid wall climb (r = -0.25), and 500-yard run (r = -0.21) when performed by recruits. Thus, VJ performance can provide useful information for law enforcement personnel.

Despite the value of the VJ in law enforcement fitness assessments, there is a lack of historical or normative data, especially for law enforcement recruits. A further consideration is that different equipment can be used to measure the VJ, including force plates, jump mats, and jump-and-reach devices (Lockie et al., 2018b; McGuigan, 2015). A jump-and-reach device involves the individual reaching and displacing vanes at the height of the jump, such that the practitioner finds the difference between standing reach height and the maximal jump height to provide the VJ metric (Lockie et al., 2018b). Jumps measured by different equipment may not be directly comparable (Nuzzo et al., 2011). Dawes et al. (2017) documented percentile rank data for the VJ measured by a jump mat performed by male patrol officers. Lockie et al. (2022c) provided normative data for police officers performing the VJ while being measured by a jump-and-reach device. Notwithstanding any equipment differences, recruits tend to outperform incumbent officers in fitness testing for a number of reasons (e.g., recruits tend to be younger, their focus is on training and they have more time to train) (Dawes et al., 2023; Lockie et al., 2020d; Orr et al., 2018). Thus, normative data for incumbent personnel may not always be directly applicable to recruits. There is normative recruit data for the standing broad jump for law

enforcement recruits (Štefan et al., 2022), but not for the VJ. Additionally, given that PAPw can be derived from the VJ (Sayers et al., 1999), and this variable has featured in law enforcement research (Cocke et al., 2016; Collins et al., 2022; Dawes et al., 2019a; Moreno et al., 2024; Moreno et al., 2019; Wiley et al., 2020), it would be also useful to present normative PAPw data for law enforcement recruits.

The generation of normative data for the VJ measured by a jump-and-reach device is useful for law enforcement training staff, as it will allow for benchmarking of recruits, in addition to highlighting those recruits who have above or below average power as measured by the VJ. The presence of VJ normative data could also assist staff with training program design for their recruits. Therefore, this descriptive study detailed percentile ranks of jump height and PAPw for the VJ assessment in male and female law enforcement recruits. Retrospective analysis was conducted on pre-existing de-identified data provided by one law enforcement agency. The data composed in this study could be used to drive training practices for law enforcement candidates, as well as recruits in the lead-up to and during academy.

Methods

Design

The cross-sectional, descriptive analysis conducted in this study was similar to previous research that has documented normative data for first responder personnel (Hernandez et al., 2021; Lockie & Hernandez, 2020; Lockie & Moreno, 2020; Lockie et al., 2020b; Lockie et al., 2022c). Retrospective analysis on de-identified recruit data provided by one law enforcement agency from 10 academy classes was conducted. Percentile rankings were produced for all recruits combined, men, and women for VJ height and PAPw derived from the VJ.

Participants

Retrospective analysis was conducted on de-identified data from 833 recruits (age: 27.21 ± 6.20 years; height: 1.73 ± 0.11 m; body mass: 80.21 ± 13.69 kg), including 683 men (age: 27.19 ± 6.10 years; height: 1.75 ± 0.09 m; body mass: 83.38 ± 12.56 kg) and 150 women (age: 27.25 ± 6.31 years; height: 1.62 ± 0.07 m; body mass: 65.47 ± 10.55 kg). All available data from the 10 academy classes was used for this study. Based on the use of archival data in this study, the institutional ethics committee approved the use of pre-existing data (HSR-17-18-370). The study followed the recommendations of the Declaration of Helsinki (World Medical Association, 1997).

Measurements and Procedures

The VJ was completed as part of a battery of fitness assessments which were completed by recruits prior to their training academy (Bloodgood et al., 2020; Collins et al., 2022; Lockie et al., 2019; Lockie et al., 2020a; Lockie et al., 2018a; Lockie et al., 2021). The other fitness assessment data were not considered in this study. Before testing, the recruit's age, height, and body mass were recorded. Height was measured using a portable stadiometer (Seca, Hamburg, Germany). Body mass was recorded by electronic digital scales (Omron Healthcare, Kyoto, Japan). Testing was conducted at the agency's training facility on a day scheduled by the staff and occurred between 9:00am-2:00pm for all classes. The weather conditions for testing were typical of the Southern California climate (Bloodgood et al., 2020).

A jump-and-reach device (Perform Better, Rhode Island, USA) was used to measure the VJ, and the same protocols were used for all academy classes (Bloodgood et al., 2020; Collins et al., 2022; Lockie et al., 2019; Lockie et al., 2020a; Lockie et al., 2018a; Lockie et al., 2021). The VJ protocols adopted by the agency staff have been shown to have very high test-retest reliability ($r > 0.99$) (Beck et al., 2015). The recruit initially stood side-on to the jump-and-reach device (on the recruit's dominant side), reached upward as high as possible, and fully elevated the shoulder to displace as many vanes as possible while keeping their heels on the ground (Figure 1A). The last vane moved became the zero reference. The recruit then performed a countermovement (no restrictions were placed on the range of countermovement; Figure 1B), with no preparatory step, and

jumped as high as possible. Jump height was recorded from highest vane moved (Figure 1C). The height of the VJ was calculated in inches by subtracting the standing reach height from the jump height, before being converted to cm. Each recruit completed two trials, with the best trial used for analysis. Peak anaerobic power measured in watts from the VJ was calculated for the best trial by using the equation from Sayers et al. (1999): *Peak Anaerobic Power (watts) = (60.7·VJ height [cm]) + (45.3·body mass [kg]) - 2055*.

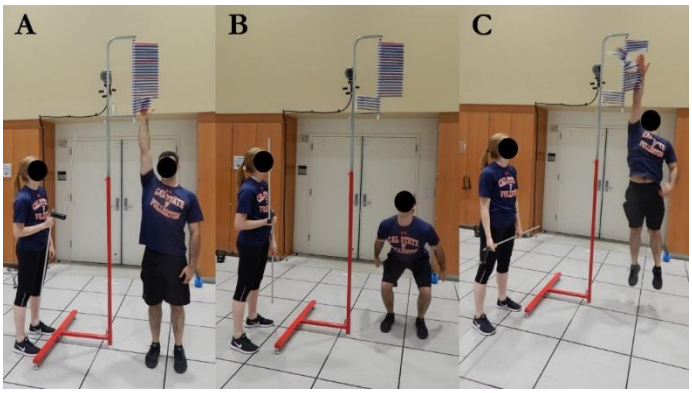

Figure 1. The countermovement vertical jump performed with a jump-and-reach device. (A) Measurement of standing reach height. (B) Preparatory countermovement. (C) Maximal jump height.

Statistical analyses

Data were collated for all recruits for the different academy classes, with the descriptive (mean ± standard deviation) data derived for VJ height and PAPw for all recruits combined, male recruits, and female recruits. Similar to previous research (Hernandez et al., 2021; Lockie & Hernandez, 2020; Lockie & Moreno, 2020; Lockie et al., 2020b; Lockie et al., 2022c), Microsoft Excel (Microsoft Corporation™, Redmond, Washington, USA) was used to calculate the percentile ranks for all, male, and female recruits. The following bands/ranks were derived for VJ height and PAPw: 90-100, 80-89, 70-79, 60-69, 50-59, 40-49, 30-39, 20-29, 10-19, and 0-9.

Results

Figures 2 and 3 displays the descriptive data for all recruits combined, men, and women for VJ height and PAPw, respectively. The percentile rank data for VJ height for all recruits, men, and women, are shown in Tables 1, 2, and 3, respectively. The number of men and women in each ranking band for all recruits is noted and number of recruits in each ranking band was documented when the sexes were analyzed separately. The PAPw percentile rank data for all recruits, men, and women, are shown in Tables 4, 5, and 6, respectively.

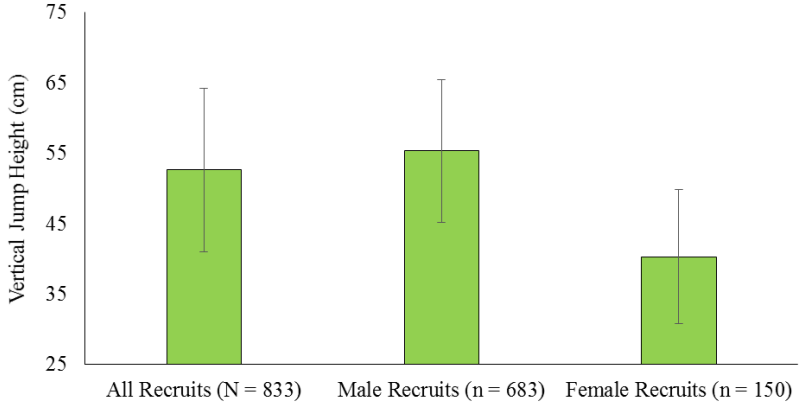

Figure 2. Descriptive (mean ± standard deviation) data for countermovement vertical jump height measured by a jump-and-reach device for all recruits, male recruits, and female recruits.

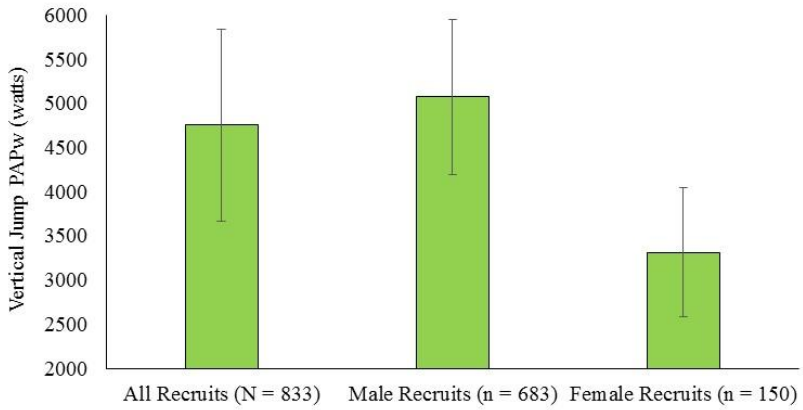

Figure 3. Descriptive (mean ± standard deviation) data for peak anaerobic power measured in watts (PAPw) derived from countermovement vertical jump height measured by a jump-and-reach device for all recruits, male recruits, and female recruits.

Table 1. Percentile rankings for countermovement vertical jump (VJ) height measured by a jump-and-reach device for male and female law enforcement recruits combined.

Percentile Rank	VJ Height (cm)	Males (n = 683)	Females (n = 150)
90-100	68.58-78.74	73	2
80-89	62.24-67.31	92	1
70-79	59.32-62.23	83	2
60-69	56.90-58.42	83	2
50-59	52.32-55.88	93	3
40-49	50.80-52.07	68	7
30-39	48.26-49.53	73	10
20-29	44.45-46.99	63	17
10-19	39.37-43.18	41	37
0-9	<38.10	30	57

Table 2. Percentile rankings for countermovement vertical jump (VJ) height measured by a jump-and-reach device for male law enforcement recruits.

Percentile Rank	VJ Height (cm)	Number
90-100	69.85-78.74	63
80-89	64.77-68.58	69
70-79	61.47-63.50	52
60-69	59.32-60.96	64
50-59	55.88-58.42	90
40-49	52.32-54.61	61
30-39	50.80-52.07	68
20-29	48.26-49.53	73
10-19	41.92-46.99	77
0-9	<41.91	66

Table 3. Percentile rankings for countermovement vertical jump (VJ) height measured by a jump-and-reach device for female law enforcement recruits.

Percentile Rank	VJ Height (cm)	Number
90-100	50.80-76.50	16
80-89	46.99-49.53	13
70-79	44.45-45.72	14
60-69	43.18	15
50-59	41.91	7
40-49	40.64	15
30-39	38.10-39.37	20
20-29	34.29-36.83	18
10-19	30.48-33.02	15
0-9	<29.21	17

Table 4. Percentile rankings for peak anaerobic power measured in watts (PAPw) derived from the countermovement vertical jump measured by a jump-and-reach device for male and female law enforcement recruits combined.

Percentile Rank	PAPw (watts)	Males (n = 683)	Females (n = 150)
90-100	6043.67-7485.23	87	1
80-89	5704.15-6043.55	83	0
70-79	5382.62-5700.49	82	1
60-69	5112.75-5381.99	79	4
50-59	4842.98-5110.25	84	0
40-49	4543.60-4839.94	83	0
30-39	4272.12-4543.52	77	5
20-29	3777.80-4271.96	68	16
10-19	3216.00-3777.19	29	54
0-9	<3211.55	11	69

Table 5. Percentile rankings for peak anaerobic power measured in watts (PAPw) derived from the countermovement vertical jump measured by a jump-and-reach device for male law enforcement recruits.

Percentile Rank	PAPw (watts)	Number
90-100	6148.41-7485.23	72
80-89	5816.81-6145.37	68
70-79	5549.66-5808.58	69
60-69	5308.61-5544.97	68
50-59	5076.75-5296.53	68
40-49	4853.77-5074.78	68
30-39	4625.22-4851.66	68
20-29	4389.66-4621.56	69
10-19	4013.99-4389.58	68
0-9	<4012.88	65

Table 6. Percentile rankings for peak anaerobic power measured in watts (PAPw) derived from the countermovement vertical jump measured by a jump-and-reach device for female law enforcement recruits.

Percentile Rank	PAPw (watts)	Number
90-100	4065.47-6145.37	16
80-89	3759.28-4058.81	15
70-79	3610.27-3754.18	15
60-69	3469.76-3605.97	15
50-59	3279.65-3456.17	15
40-49	3066.03-3261.46	15
30-39	2898.82-3052.68	15
20-29	2792.28-2894.29	14
10-19	2536.56-2766.82	15
0-9	<2526.81	15

Discussion

The VJ has featured as an entry-level fitness test for law enforcement training academies (Dawes et al., 2019b), and has been incorporated into fitness assessments of law enforcement recruits prior to academy training (Bloodgood et al., 2020; Collins et al., 2022; Lockie et al., 2019; Lockie et al., 2020a; Lockie et al., 2018a; Lockie et al., 2021). The law enforcement organization from which the current data was drawn did not use the VJ assessment as a means to remove recruits from their training academy, so there was no hard minimum cut score for the VJ that dictated employment decisions. Rather, the VJ was used as part of a testing battery to assess recruit fitness to assist with the implementation of the academy training programs. Further, the goals of this study were not to provide cut scores for VJ height and PAPw. Instead, the goals were to present normative percentile data for jump performance and PAPw in a large sample of law enforcement recruits. In addition to this, the normative data produced for VJ height and PAPw VJ can provide practical information for training staff.

It is important to present normative fitness testing data that represents all law enforcement recruits. Some law enforcement organizations will use general fitness assessments as part of a reward system during academy and may not use sex-specific standards (Lockie et al., 2020b). When considering their recruit classes, staff could use the percentile ranks produced from this research to identify where recruits currently reside with regards to their lower-body power, and how their VJ performance changes over time. Improving VJ performance is important, as absolute jump height has been related to job-specific tasks such as running and sprinting (Dawes et al., 2015; Lockie et al., 2021), body drags (Moreno et al., 2024; Moreno et al., 2019), and obstacle clearance, fence climbs, and wall climbs (Lockie et al., 2021). Percentile rank data could also be used to document improvements in recruits who may have lesser jump performance. For example, a recruit could be in the 20-29% rank after academy training, which could be considered less than ideal. However, if they started in the 0-9% rank, this would be evidence of an improved VJ that could also hopefully benefit job task performance.

To provide some context for the VJ data, when compared to 20-29 year old police officer normative data, the VJ height mean from the current study was slightly below that from Lockie et al. (2022c) (~58 cm vs. 52.63 ± 11.59 cm), who used similar methodology to measure the VJ as that from this research. The police officers from Lockie et al. (2022c) were part of a health and wellness program, so they could have been receiving exercise interventions as part of the program, or the data could have been influenced by the healthy worker effect. The healthy worker effect is where fitter officers are likely to participate in a voluntary health and wellness program (Chowdhury et al., 2017; Lockie et al., 2022c). Nonetheless, the equivalent percentile ranks

in the current study were relatively similar to the two years documented by Lockie et al. (2022c). The current study also adds normative data specific to law enforcement recruits to the literature.

Although not as common in law enforcement testing, normative PAPw metric could be useful to present to recruits as it demonstrates how they generate power with regard to their body mass. Although heavier individuals will typically have a higher PAPw (Carlock et al., 2004), if a lighter recruit experiences an increase in PAPw following training, the staff could infer they have become better at moving their body mass quickly. Moreover, it may not just be more body mass that influences PAPw. Collins et al. (2022) detailed that a greater PAPw derived from the VJ significantly ($p < 0.001$) related to more lean body mass in law enforcement recruits ($r = 0.543$-0.558). Thus, training that develops lean body mass (i.e., resistance training) could also lead to improved PAPw. Greater PAPw has been correlated with a faster 74.84-kg and 90.72-kg body drag over 9.75 m when performed by civilians (Moreno et al., 2024). Notably, Moreno et al. (2024) found that civilians who could not complete a standard body drag with a 90.72-kg dummy had a PAPw of 3599.84 ± 627.86 watts. This value would fall in the 0-9% rank for men, but the 60-69% rank for women. These data highlight the importance of PAPw for executing heavier body drags (Moreno et al., 2024), which is important with the population shift towards heavier mean body mass for men and women (Fryar et al., 2018).

Previous research has shown between-sex differences in VJ performance in law enforcement recruits (Lockie et al., 2020a; Lockie et al., 2018a; Lockie et al., 2022b), which was also reflected in the normative data from this study. When all recruits were combined for VJ height, 74% of all female recruits were in the bottom three percentile bands from 0-29%. For PAPw, 93% of women were in the 0-29% bands. These results were likely influenced by body mass being included in the PAPw calculation (Sayers et al., 1999), and women on average being lighter than men (Fryar et al., 2018). Nonetheless, when the sexes were analyzed separately, men tended to have greater values for VJ height and PAPw in the equivalent bands compared to women. This is not to say that women lack the power for a successful career in law enforcement. Indeed, similar to other law enforcement normative data studies (Lockie & Hernandez, 2020; Lockie & Moreno, 2020; Lockie et al., 2020b), there were women who outperformed many men in the VJ. Nonetheless, similar to recommendations made in previous studies (Lockie et al., 2020a; Lockie et al., 2018a; Moreno et al., 2024), what these data reinforce is that women attempting a career in law enforcement should complete specific power training prior to and during academy.

A foundation of this power training should be strength development, which is supported by research noting relationships between lower-body strength and jump performance in law enforcement populations (Dawes et al., 2019a). With effective training program design incorporating strength and power exercises, both male and female recruits could improve in their jump performance after academy training. Lockie et al. (2020c) documented improvements in VJ performance following 27 weeks of academy training in male and female law enforcement recruits, which the authors linked in part to improvements in lower-body strength. Specific to male recruits, both VJ (increase of 7.37 ± 5.91 cm) and PAPw (increase of 373.97 ± 377.90 watts) significantly ($p < 0.01$) improved following a 6-month training academy, where the fitness program incorporated a mix of muscular strength, power, and endurance exercises (Cocke et al., 2016). Although not significant ($p = 0.06$), Crawley et al. (2016) found an approximate 8% increase in VJ height in male and female police cadets following a 16-week training academy. The sex-specific normative data could aid training program design, especially for women (and possibly men with lighter body mass) who may need more targeted strength and power training before they can work safely and effectively in the field.

There are limitations for this descriptive research that should be documented. De-identified data from one agency was analyzed in this study. As fitness assessment performance can vary across agencies (Myers et al., 2019), the current normative data may not be applicable to all law enforcement organizations. This research only provided a descriptive analysis of recruit VJ height and PAPw data; the effects of VJ performance on

academy survivability and future job performance cannot be determined from the current data analysis. There was a large between-sex discrepancy in the study data (i.e., 683 men, 150 women), although this is typical of many law enforcement organizations. Jump height was measured by a jump-and-reach device. Other equipment (e.g., force plates) could provide more accurate VJ data, notwithstanding that other law enforcement organizations may use different equipment. If different equipment is used to measure the VJ, this could make normative data comparisons challenging (Nuzzo et al., 2011).

Conclusion

This study documented normative data for law enforcement recruits in the VJ, for both jump height and PAPw. With regards to between-sex comparisons, the data indicated the male recruits tended to perform better than female recruits; 74% of all female recruits were in the bottom three percentile bands for VJ height, and 93% of women were in the bottom three bands for PAPw. Female recruits will likely need specific strength and power training prior to and during academy. The provision of normative VJ height and PAPw data provide benchmarking of the lower-body power of recruits and could inform fitness training program design for academy staff.

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