A Comparison of Countermovement Jump and Squat Jump Performance between 627 State and Non-State Representative Junior Australian Football Players

Running Head: Jump performance of junior Australian Football players

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ABSTRACT

This cross-sectional study investigated differences in lower body power of state and non-state representative junior Australian football (AF) players through countermovement jump (CMJ) and squat jump (SJ) performance. A total of 627 players performed the CMJ and SJ at the end of the pre-season phase over a two-week period, with each player grouped according to their age (under 18 [U18] or under 16 [U16]), and highest competition level played (state representation, non-state representation). One-way multivariate analysis of variance (MANOVA), follow up ANOVA's, and Cohen's d effect sizes were used to identify significant main effects and between-group differences. Statistical significance was set at a <0.05. Significant small-to-moderate effect size differences were observed between competition level, with state U18 and U16 players recording greater CMJ and SJ height, and peak power (PP), compared to their non-state representative peers, respectively. Similarly, significant small-to-moderate effect size differences existed between age groups, with non-state U18 players recording greater CMJ and SJ height, and PP than non-state U16 counterparts. However, state U18 and state U16 only differed in CMJ PP. No differences were found between competition level, or age groups for the difference between CMJ and SJ jump height ($CMJSJ_{diff}$). Together, these findings suggest that state and non-state representative junior AF's may have a similar ability to utilize the stretch-shortening cycle, despite state representative players jumping higher in the CMJ and SJ.

Key Words

Youth, team sport, athletic performance, lower body power, stretch

INTRODUCTION

An athlete's ability to produce force at high velocities in unloaded performance tasks (often referred to as power in practical settings) is an important physical characteristic in team sports given its high correlation to activities such as sprinting, change of direction, and jumping (2, 14, 20, 22, 24). Two common assessments of this quality are the countermovement jump (CMJ) and the squat jump (SJ) (6, 23). The CMJ can be used to assess an athlete's capability to produce lower body force through a stretch-shortening cycle (SSC) movement, whereas the SJ can be used to assess an athlete's capability to produce lower body force solely through concentric movement (4, 6, 23). The CMJ begins from a standing position before descending to a self-selected squat depth and is immediately followed by extension of the lower limbs in an upward motion before take-off (4, 6, 23). Similarly, the SJ commences from a standing position before descending to a knee angle of 90 - 100^o which is held for at least three seconds followed by an upward motion and take-off (4, 6, 23).

It is widely accepted that the CMJ often produces a greater jump height than the SJ due to the use of the SSC (4, 23). This has led some practitioners to interpret greater differences between CMJ and SJ height ($CMJSJ_{diff}$) as a positive performance trait that is reflective of an athlete's ability to store and use elastic energy (15, 23). However, a larger $CMJSJ_{diff}$ can also be representative of an athlete's inability to reduce muscle compliance and rapidly contract the exercising muscles in the SJ (3, 23). Further, the contractile elements of muscles move into a more active state during the CMJ where a high neural drive already exists at the start of the propulsive phase with a greater number of cross bridges attached (due to the increased force at the bottom of the countermovement) when compared to the SJ, where the net force at the commencement of the propulsive phase is zero (3, 23). For this reason, the hip extensor muscles can generate more mechanical work during the initial shortening range of a CMJ compared to a SJ (3). In numerous team sports, the ability of athletes to quickly reduce the musculo-tendinous compliance and build up stimulation is especially important, and while a greater $CMJSJ_{diff}$ has traditionally been viewed as beneficial (15, 19), there is a strong argument to suggest a smaller difference should be the desired outcome (23). However, most investigations of CMJ and SJ performance of athletes have only contained a small sample size (< 50) which can lead to an overestimation of effect sizes, a reduction in the likelihood that a statistically significant result reflects a true effect, and low reproducibility of results (5).

Specifically to Australian football (AF), lower body power production is commonly assessed through CMJ height quantified using a jump and reach measurement device such as a Vertec (9, 11, 25). Research within AF has shown that CMJ performance is significantly greater in higher-level junior players (defined as selection onto a state representation team) compared to their lower-level counterparts (25), whilst at the elite level, professional starters recorded significantly greater CMJ peak power (PP) compared to non-starters (26). Further, professional AF players have been found to produce significantly greater PP in the CMJ and SJ at varying percentages of their one-repetition maximum back squat when compared to sub-elite players, despite there being no differences in maximum lower body strength or body mass (6). However, no $CMJSJ_{diff}$ in height or PP were reported (5). Thus, while these findings suggest that lower body power is an important physical characteristic for sporting performance, to date, very little is known about the $CMJSJ_{diff}$ in AF, particularly at junior levels. The purpose of this study was to investigate CMJ and SJ performance, and $CMJSJ_{diff}$ in a large sample of state and non-state representative junior AF players. Aligning with a recent view of the $CMJSJ_{diff}$ (23), it was hypothesised that while CMJ and SJ height, and CMJ and SJ PP would be greater in the state representative cohort compared to their non-state counterparts, $CMJSJ_{diff}$ would not differ.

METHODS

Experimental approach to the problem

A cross-sectional, single-session study design was used to investigate differences in CMJ and SJ height, estimated CMJ and SJ absolute PP, and $CMJSJ_{diff}$ between competition level, and age groups in junior AF players. All CMJ and SJ testing was conducted on an indoor hardwood court, over a two-week period, at the end of the pre-season training phase.

Subjects

A total of 627 junior AF players volunteered to participate in this research (17.1 ± 1.1 years, 72.1 ± 8.9 kg, 180.0 ± 7.5 cm). From this sample, 44 players were classified as under 18 (U18) state representatives (high-level), 30 were classified as under 16 (U16) state representatives, 301 were classified as U18 non-state representatives, and 252 were classified as U16 non-state representatives (see Table 1 for group descriptive). The state U18 and state U16 players were identified based on their talent to represent their State in a National competition, whereas the non-state representatives were playing in the local competition level. All players were free from any injury that would affect their ability to perform the required tests. Players and their parent/guardian were informed of the benefits and risks of the investigation prior to providing written informed consent to participate in the study. The University Research Ethics Committee approved this research (Reference H6499).

Procedures

Prior to testing, all players completed a standardised 10-minute warmup that included low intensity running and plyometrics, joint mobility exercises, and athletic drills, followed by three practice CMJ’s and SJ’s. Following this, each player performed three CMJ’s, and three SJ’s, with the order of jump type being randomised between players. Jump height was quantified by a Vertec measurement device (Swift Performance Equipment, Lismore, Australia). The quantification of CMJ and SJ height using the Vertec measurement device requires skill and coordinated movement of the upper body to reach the highest vane at the highest point of the jump. This method of quantifying jump heights is common in junior AF, and all players were familiarized with these tests prior to recording. Players completed the CMJ by performing a downward countermovement to a self-selected depth before immediately jumping and reaching to displace the highest vane on the Vertec. Players completed the SJ by descending into a visually monitored knee angle of 90^o, maintaining this position for three seconds, before jumping and reaching to displace the highest vane on the Vertec. One-minute of rest was allocated between each jump trial. Estimated absolute PP was calculated for each CMJ and SJ trial using Sayers formula (equation 1) (21) to account for any differences in body mass between the subjects. $CMJSJ_{diff}$ was calculated by subtracting SJ height from CMJ height. All data were calculated using the average of the three CMJ and SJ heights for each player (19).

$$PP = [60.7 \times \text{jump height (cm)}] + [45.3 \times \text{body mass (kg)}] - 2055$$

[equation 1]

Statistical Analyses

Mean and standard deviation (SD) for all CMJ and SJ heights, estimated CMJ and SJ PP, and $CMJSJ_{diff}$ were calculated for all players and groups. Normality was assessed both visually and statistically using a Shapiro-Wilk test of normality, confirming all variables were normally distributed. Intraday reliability of each variable was measured using an intraclass correlation coefficient (ICC) and coefficient of variation (CV) (13). A one-way multivariate analysis of variance (MANOVA) was used to identify significant main effects between competition and age groups. In the event of significant main effects and interactions, univariate ANOVA's were used to determine how CMJ and SJ characteristics differed between groups. Significant ANOVA's were followed up with Tukey's honest significant difference post-hoc analysis to control for type 1 error and assess multiple comparisons between groups. These analyses were performed in Statistical Package for Social Sciences software ([SPSS], version 22, IBM corporation, USA), with a statistical significance set at a <0.05. Finally, Cohen's d effect sizes and 90% confidence intervals were used to determine the magnitude of within- and between-group differences using the calculation (17):

$$\text{effect size} = (\text{mean group 1} - \text{mean group 2}) / \text{pooled standard deviation}$$

Threshold values of 0-0.19, 0.20-0.59, 0.6-1.19, 1.2-1.99, and > 2.0 were used to represent trivial, small, moderate, large, and very large effects, respectively (12).

****** INSERT TABLE 1 HERE ******

RESULTS

The group mean and SDs for all CMJ and SJ dependent variables are presented in Table 1. High trial-to-trial reliability was observed for all groups in the CMJ height (ICC = 0.94 – 0.97, CV = 1.9% – 2.2%), estimated CMJ PP (ICC = 0.96 – 0.98, CV = 1.4% – 1.9%), SJ height (ICC = 0.94 – 0.98, CV = 1.7% – 2.2%), estimated SJ PP (ICC = 0.81 – 0.93, CV = 2.2% –

2.1%), $CMJSJ_{diff}$ (ICC = 0.81 – 0.93, CV = 2.1% – 8.9%), and relative $CMJSJ_{diff}$ (ICC = 0.82 – 0.94, CV = 2.1% – 9.5%). Significant small to moderate effect size differences were found in CMJ and SJ variables between competition groups (state, non-state), with the state U18 group recording higher CMJ and SJ height, and estimated CMJ and SJ PP compared to the non-state U18 group. Similar significant findings were observed between the state U16 and non-state U16 groups (Table 2). No significant differences between competition level were found for absolute or relative $CMJSJ_{diff}$.

****** INSERT TABLE 2 HERE ******

Significant small to moderate effect size differences were found in CMJ and SJ variables between age groups (U18 v U16), with the non-state U18 group recording higher CMJ and SJ height, and estimated CMJ and SJ PP compared to non-state U16 group (Table 3). Estimated CMJ PP was the only variable to be significantly and moderately greater for the state U18 group compared to the state U16. No significant differences between age group were found for absolute or relative $CMJSJ_{diff}$.

****** INSERT TABLE 3 HERE ******

DISCUSSION

The aim of the study was to investigate the differences in CMJ and SJ performance measures, and $CMJSJ_{diff}$ between high and low level junior AF players. While there were significant differences between competition level and age groups for CMJ and SJ height, and estimated

CMJ and SJ PP, there were no significant differences in absolute of relative $CMJSJ_{diff}$. Traditionally, a greater $CMJSJ_{diff}$ was thought to be an indicator of superior lower body power qualities (13); however, our findings highlight that junior AF players with better CMJ and SJ performance do not exhibit any differences in $CMJSJ_{diff}$ compared to lower performing players. Although this is a cross-sectional study, these findings question the use of $CMJSJ_{diff}$ to guide training prescription for improvements in lower body power. Further, the results suggest that CMJ and SJ height may be more helpful than $CMJSJ_{diff}$ to differentiate between age group and competition level.

When comparing lower body power between competition levels, there were significant small to moderate effect size differences between age-matched state and non-state junior AF players (Table 2). Specifically, the state junior players recorded significantly greater CMJ and SJ height, and estimated CMJ and SJ PP compared to non-state players. These findings align with previous research investigating lower body power performance between competition levels in Rugby Union and Rugby League (1, 10). However, an important finding of the current study was that there were no significant differences between competition level for absolute or relative $CMJSJ_{diff}$. Together, these results highlight that significantly better CMJ and SJ height in junior AF players does not relate to differences in absolute or relative $CMJSJ_{diff}$. Further, the non-significant differences in absolute and relative $CMJSJ_{diff}$ suggest that state and non-state junior AF players have a similar ability to utilize the SSC and reduce the degree of muscle and tendon compliance, despite elite junior players performing better in the CMJ and SJ. Similarly, research has identified that superior jumping performance between different sporting populations does not always exhibit larger $CMJSJ_{diff}$ (16, 18). For example, power athletes (sprinters, throwers, and jumpers) recorded superior CMJ and SJ height compared to endurance athletes (long distance runners and triathletes), however no differences were observed in

$CMJSJ_{diff}$ between groups (18). Additionally, no differences were reported in $CMJSJ_{diff}$ between 770 junior male and female athletes across various sports (16). Together, these findings are in contrast to the traditional viewpoint that a $CMJSJ_{diff}$ is beneficial for lower body power and sporting performance (15, 19, 23).

The greatest age group differences in CMJ and SJ height, and estimated CMJ and SJ PP were observed between the non-state U18 and non-state U16 cohort, with the only significant age group difference in the state U18 and U16 cohort was in estimated CMJ PP. The non-significant differences between age groups in the state group are in contrast to a longitudinal analysis that found all physical performance tests, including CMJ, significantly improve as players progress from State U16 to State U18 (7). However, caution should be taken when comparing cross-sectional to longitudinal study designs, particularly in youth athletes who are subject to maturational influences (8). Further, similar to the competition level analysis, no significant differences were observed in absolute or relative $CMJSJ_{diff}$ between elite and sub-elite U18 and U16 age groups. Therefore, it could be suggested that elite and sub-elite U18 and U16 players have similar SSC efficiency and muscle and tendon compliance.

Despite the novelty of this study, it is not without limitations. For example, estimating power via valid equations versus direct assessment can reduce the accuracy of PP measures. In addition, the cross-sectional study design does not allow for discussion on the causal relationship between $CMJSJ_{diff}$ and jumping ability or other performance related physical qualities. It is also important to recognize the unbalanced sample size, with the state representatives at both U18 and U16 levels heavily outnumbered against their non-representative counterparts. This, however, was somewhat inevitable and uncontrollable given selection procedures within the state in which this study took place, limiting the number of positions on the state program given constraints related to resources. Thus, future research could include national testing procedures, thereby increasing the number of state representatives, potentially gaining a wider representation of CMJ and SJ performance of junior AF players.

In conclusion, the findings of this study demonstrate that state junior AF players have superior lower body jump performance compared to their non-state counterparts, as measured through CMJ and SJ height, and estimated CMJ and SJ PP. Similar results were found between age groups in the non-state representative cohorts, while there were no differences in lower body power performance between state U18 and state U16 cohorts. Further, no significant differences were observed in absolute or relative $CMJSJ_{diff}$ between competition level or age group comparisons. Together, it could be suggested that state and non-state junior AF players have a similar ability to utilize the SSC and degree of muscle and tendon compliance, despite state junior players performing better in the CMJ and SJ. Considering this, it is recommended that practitioners yield caution when using $CMJSJ_{diff}$ as an indicator of vertical jump performance.

PRACTICAL APPLICATIONS

The CMJ and SJ are commonly used by practitioners to assess lower body power capacities of athletes, with the $CMJSJ_{diff}$ often used for training prescription. We recommend the continued use of these lower body power assessments within junior AF, as they can differentiate between higher and lower level players, however caution should be taken when using $CMJSJ_{diff}$ as an indicator of vertical jump performance and to differentiate between competition levels. Further, it is recommended that practitioners seek to improve lower body power in junior lower level players to help provide continued opportunities for selection onto a state representative team. Finally, we recommend that practitioners aim for a small difference in $CMJSJ_{diff}$ through enhancing concentric power, rate of force development, and athletes’ ability to reduce the degree of muscle and tendon compliance.

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Table 1. Descriptive data on state and non-state junior AF players

		State U18	State U16	non-State U18	non-State U16
Subject Characteristics	**Age (y)**	18.1 ± 0.5	16.2 ± 0.3	17.9 ± 0.7	16.0 ± 0.6
	Height (cm)	184.2 ± 8.0	183.8 ± 8.2	181.4 ± 7.0	177.2 ± 7.0
	Body mass (kg)	77.9 ± 7.3	74.0 ± 7.3	74.4 ± 8.1	68.0 ± 8.5
Countermovement Jump	**CMJ (cm)**	59.7 ± 6.8	56.9 ± 5.5	55.5 ± 6.1	52.0 ± 6.4
	CMJ PP (W)	5103 ± 475	4748 ± 374	4687 ± 513	4183 ± 545
Squat Jump	**SJ (cm)**	54.7 ± 7.1	53.1 ± 5.9	51.9 ± 6.0	48.5 ± 7.0
	SJ PP (W)	4800 ± 521	4519 ± 363	4469 ± 504	3968 ± 587
CMJ – SJ difference (height)	**Absolute (cm)**	4.9 ± 4.4	3.8 ± 3.5	3.6 ± 3.2	3.5 ± 4.0
	Relative (%)	8.2 ± 7.3	6.6 ± 6.3	6.4 ± 5.7	6.7 ± 7.8

CMJ = countermovement jump; SJ = squat jump; CMJ PP = countermovement jump absolute peak power; SJ PP = squat jump absolute peak power.

Table 2. Differences in lower body power between AF junior competition levels

		State U18 vs non-State U18				State U16 vs non-State U16			
		Mean Difference	**% Mean Difference**	**Effect Size**	***p*-value**	**Mean Difference**	**% Mean Difference**	**Effect Size**	***p*-value**
Countermovement Jump	**CMJ (cm)**	4.2 ± 2.6	7.1 ± 4.4	0.68 ± 0.32	< 0.01	4.8 ± 3.1	8.5 ± 5.5	0.77 ± 0.38	< 0.01
	CMJ PP (W)	416 ± 215	8.1 ± 4.2	0.82 ± 0.32	< 0.01	565 ± 258	11.9 ± 5.4	1.07 ± 0.38	< 0.01
Squat Jump	**SJ (cm)**	2.8 ± 2.7	5.2 ± 5.0	0.46 ± 0.32	0.04	4.6 ± 3.2	8.6 ± 6.1	0.66 ± 0.38	< 0.01
	SJ PP (W)	332 ± 222	6.9 ± 4.6	0.66 ± 0.32	< 0.01	550 ± 266	12.2 ± 5.9	0.97 ± 0.38	< 0.01
CMJ – SJ difference (height)	**Absolute (cm)**	1.4 ± 1.51	27.7 ± 30.4	0.41 ± 0.32	0.09	0.24 ± 1.81	6.3 ± 48.0	0.06 ± 0.38	0.99
	Relative (%)	1.8 ± 2.8	22.4 ± 34.2	0.31 ± 0.32	0.33	-0.2 ± 3.4	-2.5 ± 51.1	-0.02 ± 0.38	0.99

CMJ = countermovement jump; SJ = squat jump; CMJ PP = countermovement jump absolute peak power; SJ PP = squat jump absolute peak power.

Table 3. Age group differences in lower body power between AF junior competition levels

		State U18 vs State U16				non-State U18 vs non-State U16			
		Mean Difference	**% Mean Difference**	**Effect Size**	***p*-value**	**Mean Difference**	**% Mean Difference**	**Effect Size**	***p*-value**
Countermovement Jump	**CMJ (cm)**	2.9 ± 3.8	4.8 ± 6.4	0.46 ± 0.47	0.21	3.5 ± 1.4	6.3 ± 12.5	0.56 ± 0.17	< 0.01
	CMJ PP (W)	355 ± 315	7.0 ± 6.2	0.81 ± 0.47	0.02	504 ± 114	10.8 ± 2.4	0.96 ± 0.17	< 0.01
Squat Jump	**SJ (cm)**	1.7 ± 3.4	3.0 ± 7.3	0.25 ± 0.47	0.70	3.4 ± 1.4	6.6 ± 2.8	0.53 ± 0.17	< 0.01
	SJ PP (W)	281 ± 326	5.9 ± 6.8	0.61 ± 0.47	0.12	500 ± 117	11.2 ± 2.6	0.92 ± 0.17	< 0.01
CMJ – SJ difference (height)	**Absolute (cm)**	1.2 ± 2.2	24.3 ± 44.6	0.30 ± 0.47	0.50	0.07 ± 0.8	2.0 ± 22.2	0.02 ± 0.17	0.99
	Relative (%)	1.6 ± 4.1	20.0 ± 50.1	0.24 ± 0.47	0.73	-0.4 ± 1.5	-5.7 ± 23.3	-0.05 ± 0.17	0.92

CMJ = countermovement jump; SJ = squat jump; CMJ PP = countermovement jump absolute peak power; SJ PP = squat jump absolute peak power.