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The Occurrence of Different Vertical Jump Types in Basketball Competition and their Relationship with Lower-Body Speed-Strength Qualities

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ABSTRACT

Jumps occur frequently in basketball and can be executed from a single-leg take-off following a run-up or bilaterally from a standing start. Understanding the type of jumps performed in competition and how different muscular qualities influence their performance, informs training prescription. Firstly, to quantify the occurrence of different jump types performed in competition an analysis of 15 semi-professional basketball games was undertaken. Secondly, to understand the influence of muscular qualities on performance of different jump types, Semi-professional male basketball players (N=17) performed jump tests; standing vertical jump, running vertical jumps with a double leg take-off (RVJ2) and a single leg take-off (RVJ1) and tests of lower-body speed-strength; reactive strength index (RSI) from a drop jump, counter movement jump (CMJ) and squat jump. A stationary approach was employed for 69%, a running approach for 26% and a one-step approach for 5%. RVJ1 displayed non-significant (P=0.07) moderate correlation with jump height attained from the CMJ (r=0.439) and a very large (r =.806) significant (P<0.01) correlation with RSI. Most jumps were executed from a stationary start with a bilateral take-off while a run-up occurred prior to a substantial proportion of jumps. Jumps with a single-leg take-off from a run-up strongly correlate with RSI.

Keywords: Plyometric training, Reactive strength, Power

INTRODUCTION

Basketball is a team-based invasion sport that is characterised by distinctive movement patterns (Reina et al., 2020; Abdelkrim et al., 2007; McInnes et al., 1995). The ability to jump for height underpins many basketball-specific skills such as shooting, rebounding, dunking, lay-ups, blocking and defending shots. As such, jumping is a prioritised movement in training programs. Previous research has indicated that elite male basketball players average approximately 45 vertical jump acts per game (Abdelkrim et al., 2007; McInnes et al., 1995). However, within a game of basketball a range of strategies can be employed when performing a vertical jump. These include one- or two-foot take-offs and the incorporation of an approach from a stationary position or a run-up of varied lengths and speeds.

Previous literature suggests that multiple strength qualities contribute to the performance of vertical jumps, however, different types of vertical jumps require a greater relative contribution from specific speed-strength qualities (Ebben & Petushek, 2010; Haff et al., 2010; Sheppard et al., 2008; Young et al., 1999). The term 'speed-strength' can be used to describe a movement that requires the expression of force rapidly (Schmidtbleicher, 1992). 'Power' can also be used to describe rapid force production however, unless specifically measured in Watts the use of a more general term such as 'speed-strength' is recommended (Knudson, 2009). Speed-strength is a noted underpinning muscular

quality for performance of standing bilateral vertical jumps due to the presence of a long-slow stretch-shortening cycle (SSC) characterised by a take-off time of approximately 500ms (Ebben & Petushek, 2010). Whereas, vertical jumps from a run-up are more influenced by reactive strength (Sheppard et al., 2008). Reactive strength is a measure of an athlete's ability to generate force in a short-fast SSC characterised in a jump by a take-off time of <250ms (Young et al., 1999). This notion is supported by a study in a population of elite volleyball athletes which found that their ability to tolerate high stretch loads imposed via a drop jump from a height of 35cm to be a critical component in the successful execution of spike jumps occurring from a three to four step run-up (Sheppard et al., 2008). Whilst there is commonality within the underpinning qualities that influence performance in all vertical jumps, the relative importance of specific speed-strength qualities may vary depending upon the take-off strategy utilised (Young et al., 1999). For example, a stationary vertical jump from a 2-foot take-off, and a vertical jump with a single leg take-off from a 1-step approach has been previously shown to have little shared commonality and therefore are considered separate skills that differ in contributions from muscular qualities (Young et al., 1999).

The published literature into jumping in basketball athletes has primarily focused on better understanding the frequency of and underlying physical qualities related to bilateral jumps from a standing start (Abdelkrim et al., 2007; Hakkinen, 1997). However, to date no study has categorised the types of jumps observed in competition based upon the movement strategy (i.e. single or double leg take-off; stationary or running approach). Greater understanding of the occurrence of different jump types executed in competition can help coaches better prioritise specific jump training. Moreover, understanding the relationship between select speed-strength qualities and the performance of different jump types in basketball athletes will help practitioners prescribe training that is more specific to the demands of the sport. Therefore, the purpose of the investigation was two-fold and is presented in the manuscript as two separate but overlapping studies. Firstly, to quantify the occurrence of different vertical jump types in basketball competition (investigation one). Secondly, to determine the strength of the relationship between different speed-strength qualities assessed via countermovement jump (CMJ), squat jump (SJ) and drop jump (DJ) and the performance of different vertical jump types (investigation two).

MATERIALS AND METHODS

The investigations detailed within this manuscript were designed to comply with Strengthening Reporting in Observational Studies in Epidemiology (STROBE) Statement (Von Elm et al., 2014). To understand the frequency of different vertical jump types used in basketball competition, investigation one employed a notational analysis of footage of 15 games from a semi-professional basketball team competing in a second-tier competition in Australia. To understand the relationship between various speed-strength qualities and the execution of these jump types, an explanatory correlational research study design was used for investigation two.

Participants

Convenience sampling was used to determine the sample size for both studies. Participants (N=17) were members of a semi-professional male basketball team competing in Australia's second-tier professional league with a mean age of 20.1 (±2.4yrs), height of 189.0 (±9.2cm), and body mass of 87.0 (±16.3kgs). All participants were free of injury and in the competition phase of their periodised training program at the time of data collection. Ethical approval for this investigation was obtained by the ***** University (name of university excluded for peer-review) Human Research Ethical Committee, application number C19-009. All participants had prior experience performing vertical and drop jump testing as part of their routine monitoring program.

Procedures

Investigation one: Footage from 15 games of the team's regular season were analysed. All games were filmed using an iPad (Apple Inc.,California, USA) with a wide angle lens sampling at a frame rate of 240fps. The devices were attached to a tripod positioned at half-court and elevated 10-12m to provide coverage of the full-court. For the purpose of this investigation a jump was defined as any activity whereby a player breaks foot contact with the floor and projects into the air off one or two feet (Abdelkrim et al., 2007; McInnes et al., 1995). Jumps were then categorised by the approach used: stationary, where no step was used prior to take-off; one-step, where one approach step was used prior to take-off; and running, where an approach of two steps or greater was used prior to take-off. Additionally, the take-off strategy was

categorised as a single or double-leg. A group of eight research assistants led by the lead author (ST) coded the first game together to ensure consistency in definitions and subsequent categorisation of jump types. For the remaining 14 games the research assistants were paired and assigned four or five of the remaining games to analyse together. If during analysis questions were raised regarding the optimal categorisation of a jump, the entire group re-convened to view and discuss the specific scenario in question until a consensus decision regarding the categorisation was achieved.

Investigation two: The jumping performance and the athlete's lower body speed-strength capabilities were assessed following a standardised warm-up which consisted of jogging, dynamic stretching targeting key musculature of the lower body and submaximal attempts of the standing and drop jumps. All participants had been familiarised with performing various vertical and drop jump protocols as part of their physical preparation program prior to undertaking the testing.

Tests of jumping performance

Tests of jumping performance used in this investigation were designed to replicate the jumps observed in the analysis of game footage. These jumping performance tests consisted of a stationary bilateral vertical jump (SVJ), running vertical jump with a single-leg take-off (RVJ1) and a running vertical jump with a bilateral take-off (RVJ2). All jump heights were measured using a Yardstick device (Swift Performance, Australia). The standing vertical jump was conducted with the athlete standing directly below the vanes of the Yardstick then performing a self-selected countermovement before jumping as high as possible. The RVJ1 and RVJ2 consisted of a self-selected run-up then a maximal jump from a single-leg and bilateral take-off, the only restriction regarding the run-up was that it was required to be greater than two-steps. Both the RVJ1 and RVJ2 jump tests were video recorded using an iPad (Apple Inc.,California, USA) sampling at a frame rate of 240fps using the Hudl Technique mobile application (Hudl, Nebraska, USA) to determine the differences in ground contact time during the take-off phase of the jump. These contact times were determined by subtracting the time on the video at the first instant of ground contact from the time at the last point of contact prior to take-off to the nearest 1/240th of a second. For all vertical jumps, athletes were provided with as many attempts as possible to attain their maximal jump height measurement with complete rest of 3-5 minutes provided between attempts.

Tests of lower body speed-strength

Tests to assess the lower body speed-strength of the athletes included a squat jump (SJ) for assessment of concentric only speed-strength, CMJ for long-slow SSC speed-strength and a drop jump (DJ) for determination of reactive strength index (RSI) as an assessment of short-fast SSC speed-strength. The SJ involved the use of a lightweight bar (0.4kg) placed on the athlete's shoulders attached to a linear position transducer (GymAware, Kinetic Performance, Australia). The athlete was instructed to squat to a depth that felt comfortable in their natural jumping motion and hold this position for 3-seconds to remove any influence from the SSC on performance of the jump (Sheppard & Doyle, 2008). From this position the athlete was instructed to jump for maximal height with no pre-stretch movement. If a countermovement was observed the attempt was discarded. The CMJ also utilised the lightweight bar attached to the linear position transducer placed across the athlete's shoulders to isolate force production to the lower extremities. The athlete performed a countermovement to a self-selected depth then immediately executed a jump for maximal height (Talpey et al., 2016). Three attempts of the SJ and CMJ were performed with the jump that elicited the greatest height retained for statistical analysis. It should be noted that jump height was selected as the sole speed-strength variable to be retained for analysis from the SJ and CMJ because it was also the primary variable for the performance-based jump tests.

For the drop jump, the athlete stood on a box with their hands akimbo. The athlete then dropped off the box and performed a maximum vertical jump with minimal time spent on the contact mat (Swift Performance, Australia). The specific instructions provided to the athlete were to "jump for maximal height and with minimal contact time" (Young et al., 1997). As a contact mat was used for this assessment, jump height was derived from a calculation of flight time. Therefore, careful consideration was paid by two members of the research team (ST & WY) to ensure the body position of the athlete was the same at both take-off and landing. For athletes that are better able to tolerate greater eccentric loads, RSI can be enhanced with an increase in drop height (Young et al., 1997). Therefore, the DJ

was performed from both a 30cm and 45cm box to ensure that the athlete's best RSI was captured. The athlete's RSI was calculated as the jump height (cm) divided by the contact time (s) (Young et al., 1997). The attempt with the greatest RSI was then recorded as the best attempt regardless of the drop height it was attained from.

Statistical Analysis

All statistical analyses were undertaken with the Statistical Package for the Social Sciences (SPSS) version 26 (IBM, New York, USA). For investigation one, descriptive statistics presented as the proportion of the total number of jumps performed were calculated for the different approaches and take-off strategies observed in competition. For investigation two, a Shapiro-Wilk test was employed to test the normality of the data. Pearson's correlations were used to examine relationships between the measures of vertical jumping performance and lower-body speed-strength qualities. The following descriptive terms were used to describe the strength of the relationships between variables; r=0.0-0.09 (trivial); 0.1-0.29 (small); 0.3-0.49 (moderate); 0.5-0.69 (large); 0.7-0.89 (very large); 0.9-1.0 (nearly perfect) (Hopkins et al., 2009).

Additionally, an independent samples t-test was conducted to determine whether there was a statistically significant ($p<0.05$) difference in contact times between the RVJ1 and RVJ2. Hopkin's effect sizes were calculated using a publicly available spreadsheet to determine the magnitude of the difference between contact times during RVJ1 and RVJ2 (Hopkins et al., 2007).

RESULTS

Investigation one: Analysis of jump types performed in competition

In total, 2202 jumps were analysed over 15 games for an average of 146.8 ± 19.0 jumps per game for the team. A stationary approach was used for 1,519 (69%) of all jumps, a running approach for 572 (26%) and a one-step approach for 1101 (5%). A double leg take-off was used for 1827 (83%) of jumps and single-leg for 374 (17%).

Investigation two: Relationships between speed-strength qualities and different jump types

The means and standard deviations for vertical jump heights from both the performance tests as well as the measures of speed-strength are presented in Table 1.

Table 1. Mean and standard deviations of jump height in vertical jump tests. SVJ = standing vertical jump; RVJ1= running vertical jump with single leg take-off; RVJ2 = running vertical jump with bilateral take-off; SJ = squat jump; CMJ = countermovement jump; RSI = reactive strength index.

	Mean	SD
Jump Performance		
SVJ (cm)	60.9	6.1
RVJ1 (cm)	75.4	10.3
RVJ2 (cm)	72.9	7.3
Speed- Strength		
SJ (cm)	42.3	6.4
CMJ (cm)	46.4	6.4
RSI (cm/s^{-1})	187.8	55.42

All of the vertical jump performance measures displayed a statistically significant large to very large correlation with each other (Table 2.). Standing vertical jump had a statistically significant very large correlation with RVJ1 (P=0.01; r=0.710) and RVJ2 (P=0.01; r=0.788), while there was a statistically significant (P=0.008) large correlation observed between RVJ1 and RVJ2 (r=0.618). Additionally, the relationships between the jump height attained from the tests of speed-strength displayed statistically significant large to very large correlations with each other (Table 2.). A statistically significant (P=0.01) large correlation was found between jump height from the SJ and CMJ (r=0.789) while RSI demonstrated statistically significant large correlations with SJ (P=0.007; r=0.629) and CMJ (P=0.01; r=0.598). Running vertical jump from a single-leg take-off showed a non-significant (P=0.07) moderate correlation with jump height attained from the CMJ (r=0.439) and a very large (r=0.806) statistically significant (P=0.01) correlation with RSI.

A statistically significant (P=0.01) large difference in the mean take-off time was found between RVJ1 (0.263 ± 0.48s) and RVJ2 (0.344 ± 0.53s). The mean (±SD) take-off times for RVJ1 and RVJ2, P-value and effect size are presented in Table 3.

Table 2. Correlation matrix of vertical jump tests and tests of speed-strength qualities. * = statistically significant P <0.05. SVJ = standing vertical jump; RVJ1= running vertical jump with single leg take-off; RVJ2 = running vertical jump with bilateral take-off; SJ = squat jump; CMJ = countermovement jump; RSI = reactive strength index.

	SVJ	RVJ1	RVJ2	SJ	CMJ
RVJ1	0.710* (very large)				
RVJ2	0.788* (very large)	0.618 (large)			
SJ	0.538* (large)	0.494* (moderate)	0.612* (large)		
CMJ	0.555* (large)	0.439 (moderate)	0.609* (large)	0.789* (very large)	
RSI	0.652* (large)	0.823* (very large)	0.688* (large)	0.629* (large)	0.598* (large)

Table 3. Comparison of contact times between different jump types. RVJ1 = Running vertical jump single-leg take-off; RVJ2 = Running vertical jump bilateral take-off.

Jump Type	Contact time (s)	% Difference	P-value	Effect Size (Descriptor)
RVJ1	.263 (±.048)	31%	P=0.01	1.6 (Large)
RVJ2	.344 (±.053)			

DISCUSSION

The aims of the investigations within this manuscript were to (i) quantify the occurrence of different vertical jump types in basketball competition and (ii) distinguish how speed-strength qualities relate to different vertical jump types. The main findings from this investigation were that a range of vertical jump types are executed during basketball competition, and a running vertical jump with a single-leg take-off displayed a favourable relationship with reactive strength that was not observed with the other jump types. This information can help inform the prioritisation and selection of training methods to improve jumping in basketball.

From investigation one, when categorising approach types, a stationary approach was used for 69% of jumps, a runup for 26% and 5% incorporated a one-step approach. When categorised by take-off, a bilateral strategy was used for 83% of jumps and a single-leg for 17%. Previous time-motion analysis studies have highlighted the importance of jumping in basketball competition, however none have categorised jumps to the level of different approaches and take-offs (Reina et al., 2020; Abdelkrim et al., 2007; McInnes et al., 1995). Understanding of the variety of jumps that are performed in basketball can be used by coaches when developing their needs analysis to enhance the specificity of their training. From the results of the current study bilateral jumps from a stationary start are the most common jump type, however, jumps from a run-up and a single-leg take-off did occur and coaches should account for these when developing programs to enhance jump performance in basketball athletes. These findings can also provide impetus for further research to understand in what specific contexts within a game do these jump types occur. For example, it is still unknown whether jumps from a running approach and single-leg take-off frequently occur during offensive transitions among players of a specific position.

The correlations between the three measures of vertical jump performance indicated that there are significant relationships between each test, however, the extent varied amongst the jumps. This finding is in agreement with previous research that has reported manipulating the run-up speed, distance and the take-off strategy in jump types resulted in 28% common variance (Young et al., 1999). In the current study, the greatest amount of commonality between measures of vertical jump performance was the 62% observed between the standing vertical jump and the running vertical jump with a bilateral take-off. This result is not surprising as the body positioning during the execution of the countermovement phase of a standing vertical jump and take-off from a bilateral vertical jump from a run-up are similar. Whereas, the lowest commonality between measures of vertical jump performance

was observed between the running vertical jump with a single-leg take-off and the running vertical jump with a bilateral take-off. While these jumps displayed a large correlation there was only 38% commonality between them, indicating that 62% of performance in these jumps is influenced by separate factors and they cannot be considered synonymous. Rationale for the lack of commonality can be drawn from the differing technical demands of the jump types. For example, in a single-leg jump the athlete is required to coordinate the movement of the free leg to generate momentum leading to a greater take-off velocity and ultimately jump height (Isolehto et al., 2007).

Another characteristic difference between the jumps was the difference in contact times between a running vertical jump with a single-leg take off compared to a running vertical jump with a bilateral take off. The average contact time for a single-leg take-off was 30% shorter than that observed in a bilateral take-off, something that has not been explored in previous research. This finding indicates that during the execution of a running vertical jump with a single-leg take-off the SSC demands can be characterised as short and fast compared to those with a bi-lateral take-off (Schmidtbleicher, 1992). Potential reasoning for the longer contact time observed with the bilateral take-off is that athletes landed on each foot from the running approach asynchronously, which is a technique that has been previously reported in spike jumps performed in volleyball (Wagner et al., 2009). Additionally, in a bilateral jump from a run-up the breaking force prior to take-off is spread across both legs as opposed to only one leg when a single-leg take-off is used. Meaning that a greater eccentric load must be tolerated in a shorter time frame by the support leg (Wagner et al., 2009). This finding helps to explain why reactive strength should be considered more important for this type of jump, hence the very large relationship observed between reactive strength index and a running vertical jump with a single-leg take-off (r=0.823) that was not observed when correlated with a bilateral take-off (r=0.688).

Interestingly, a running vertical jump with a single-leg take-off displayed only a moderate correlation with the height attained from the squat jump (concentric only speed-strength) and the countermovement jump (slow SSC speed-strength). This finding reinforces that reactive strength is likely to have a greater relative importance than concentric only force production and slow SSC speed-strength for the performance of a running vertical jump with a single-leg take-off. Previous research on running vertical jumps also found those executed from a single-leg take-off to correlate higher with reactive strength than slow SSC power (Young et al., 1999). However, the novelty of the findings from the current investigation is that the results highlight different contributions from these muscle qualities to performance in the running vertical jumps with single-leg compared to a bilateral take-off.

Although not a specific research question, from the data collected during this investigation an analysis of an athlete's ability to capitalise on a run-up approach could be undertaken. Due to the relatively high eccentric loads typical in jumps following a run-up, the athlete's reactive strength may help them better exploit the approach, and therefore some athletes may demonstrate a substantially greater benefit from using a run-up. A concept described as the "run-up utilisation index" (RUI) to aid in the explanation of an athlete's ability to exploit the run-up phase can be presented. The RUI can be expressed as the percentage gain in jump height when incorporating a run-up compared to a standing vertical jump. By determining the RUI, coaches may be able to diagnose an aspect of jumping performance that can be targeted for improvement. For example, if a basketball athlete attains a jump height of 85cm from a standing position with a bilateral take-off and a jump height of 87cm from a run-up with a single-leg take-off, the relatively small 2.4% increase in jump height would highlight that the athlete requires training to improve running vertical jump technique (i.e. utilisation of the free leg to increase momentum) and the underlying physical quality of reactive strength. A secondary analysis from the data indicates that a statistically significant (P=0.032) large relationship was found between RSI and run-up utilisation index from a running vertical jump with a single-leg take-off (r=0.521). While, a non-significant (P=0.77) trivial relationship was found between RSI and run-up utilisation index from a running vertical jump with a bilateral take-off (r=0.097). This concept would require further investigation into its reliability and validity and should be studied further.

The results presented within this manuscript should be considered alongside its limitations. This study utilised a relatively small convenience sample of basketball athletes who are experienced jumpers and results may differ in a population of athletes with less experience with jumping tasks. Additionally, jump height was used as the sole measure of speed-strength which limits the ability to explore the underlying kinetic and kinematic strategies

employed by the athletes when executing the various vertical jumps. It is possible that athletes utilise different combinations of muscular strength, power and speed when performing the different vertical jump types and a detailed force production strategy could provide sport-scientists and strength and conditioning coaches with additional insight that could inform their training prescription.

CONCLUSION

The relative contribution of speed-strength qualities varies with different types of jumps and in the sport of basketball a proportion of jumps are performed following a run-up and incorporate a single-leg take-off. Therefore, practitioners who work within basketball should determine what jump types individual players need to improve on then determine which speed-strength qualities to target when aiming to develop jumping ability specific to what occurs in competition. Vertical jumps from a standing start or a run-up with a double leg take-off can be enhanced through more general speed-strength training methods such as jump squats. However, when an athlete is required to jump using a run-up approach with a single-leg take-off, their capacity to tolerate high stretch loads with large eccentric demands is important and underpinned by their reactive strength. Therefore, more specific methods such as plyometric training emphasising maximal jump heights with minimal ground contact times should be employed. To enhance specificity and align with the inter-muscular coordination demands of jumping from a run-up with single-leg take-off, the plyometric training should incorporate single-leg landings and take-offs with contact times of approximately 0.25 sec. Additionally, testing both standing and running vertical jumps and comparing the results to each other to calculate the RUI may help practitioners diagnose an aspect of performance that can be enhanced through technical training and the development of underlying physical qualities.

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CONFLICTS OF INTEREST

The authors certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

AUTHORS' CONTRIBUTIONS

Authors ST, AS, WY, MM and MO have given substantial contributions to the conception or the design of the manuscript. All authors contributed to the acquisition and interpretation of the data. ST, AS and WY contributed to the analysis of the data. All authors have participated to drafting the manuscript, author ST revised it critically. All authors read and approved the final version of the manuscript.

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