VERTICAL JUMP ABILITY OF ELITE VOLLEYBALL PLAYERS COMPARED TO ELITE ATHLETES IN OTHER TEAM SPORTS

Successful sporting performance at elite levels of competition often depends heavily on the explosive leg power of the athletes involved. In many individual sports such as Track and Field events, Gymnastics and Diving the ability to use high levels of strength as quickly and as explosively as possible is essential to perform at elite levels. Many team sports also require high levels of explosive power, such as Basketball, Volleyball, Netball and the Rugby and Football codes for success at elite levels of competition. Explosive power comes from the development of speed strength and pure strength. Power represents the amount of work a muscle or muscle group can produce per unit of time (1,13,21,26). Until recent years power as it relates to sports performance has been the subject of limited research, but in the last decade or so researchers have realised the importance of training for power in a wide variety of sporting activities (7,9,26,27,31))

Vertical and horizontal jumping, in its many different forms, requires high levels of explosive muscular power. The double legged volleyball spike jump and block jumps are very different in technique, but fundamentally they are similar(16,24,25). Basketball players typically jump from one leg to perform a lay up, and from two legs to rebound jump, again both are very different styles of jumping which are fundamentally similar in their movement patterns.(16,29) Different jumping styles also involve very different approaches and run ups which increase or decrease the velocity of the movement performed, depending on the type of jump.(29,32) It has been suggested that different styles of jumping require different strength properties and that training for one type of jumping technique will not necessarily improve performance in another style of jumping.(32)

There have been many research studies that have investigated leg power as it relates to vertical jump (17,25,32), and how to develop leg power through various weight training (1,2,4,6,7,14), and plyometric training techniques(1,2,26,27). Data has been produced for many elite individual and team sport athletes for physical and physiological characteristics, including standing vertical jump scores, related to specific sports performance(3,10,20,25). There is limited research available however, comparing athletes of different sporting disciplines in vertical jump ability, in an attempt to explain why athletes in some sports perform better at vertical jump than athletes in other sports.

The focus of this literature review was to examine the available research relating to vertical jump ability of elite volleyball players, and to compare this with available data on other elite team sport athletes. The later part of the review will discuss some possible reasons for variations in vertical jump ability exhibited by athletes from different training backgrounds.

Previous research has shown that there is a strong correlation between V.J. ability and explosive leg power. The basic Counter Movement Jump (CMJ), or 'Sargent Chalk Jump Test' is the V.J. test most often referred to in current literature. Johnson and Nelson (1974) as cited in (22) report that the reliability of this test of leg power at .93 with the validity coefficient being .78. The objectivity of the test is reported to be .93. Other methods of testing power in the lower body include cycle ergometer tests, countermovement jumps (14,22) static jumps, force platforms, short sprints, maximum weight lifts (9), leg press (4),standing broad jumps (7,18) as well as isometric (9) and isokinetic tests (6,28).

Other research has suggested that this test is not as effective at testing muscular power output (in conjunction with the Lewis formula and nomogram),

and should be used more correctly to monitor and compare progress of a power training program (10,17).
Sawula (1991) in (25) has reported vertical jump scores for selected elite level volleyball players;-

- 1988 Canadian men's team 92cm(average) 6cm (SD)
- 1988 Canadian uni. team 86cm (average) 7cm(SD)
- Chinese men's team 86cm (average)
- Chinese women's team 82cm (average)
- 1987 Canadian women 65cm (average)

Normative data relating to V.J. performance for elite performers in other team sports was hard to come by. However individual researchers have published some literature relating to this area.

NCAA Div. 1 male football players 76cm (average) 7.8cm(SD)(3)
NCAA Div.1 male basketball players 71cm (average) 10.4cm(SD)(20)
Canada male field hockey team 62cm (average)(25)
French Canada soccer team 67cm (average)(25)

Factors Affecting Vertical Jump Ability

There are several factors which affect the ability of an athlete to successfully perform a standing vertical jump, which can be identified by physiological and other sports testing procedures.
Komi, in Kaneko et. al.(19) states that the specific composition of muscle fibres of the individual athlete will affect the development of power. Athletes with a high percentage of Fast Twitch (FT) muscle fibres are able to develop greater amounts of explosive power. This is supported by Wilson et. al (31) and Sale (23) who also refers to several neural adaptations which affect muscular power, such as motor unit activation, motor unit synchronisation and the specificity of the movement pattern.
The initial levels of strength of the athlete and the ability to make use of a Stretch Shorten Cycle (S.S.C.) will also effect development of power (1,9,13,14,23,26,31). Athletes who are trained in jumping technique such as basketball and volleyball players should be able to utilise a much more forceful pre-stretch for production of an efficient S.S.C. than untrained athletes.(23). The possible existence of two different types of S.S.C. has also been suggested by Schmidtbleicher (1990) in (32) A Long S.S.C. and a Short S.S.C. which are developed by specific types of training, and are mutually exclusive of each other. The use of elastic and contractile energy for producing dynamic muscle contractions as required in maximum power sports has been well documented (1,,4,9,13,19,22,26).
Other factors which have been shown to affect vertical jump performance are, effective use of the arms for increased vertical velocity(16), trunk extension, head movements and utilisation of a countermovement to initiate the stretch shorten cycle (S.S.C)(16,29,32). These actions are a natural movement during a jump for most athletes, however they occur in different degrees between jump trained and non-jump trained subjects.(?)
Upper body and abdominal (trunk) strength has also been shown to be a contributing factor to vertical jump performance.(5,8,26) Strength in the upper body, particularly the arms and shoulders helps to increase the Strength throughout the trunk region creates solid posture to help maximise jumping technique, and also to maximise power production and transferral of forces between the upper and lower body.
The fact that an arm swing is so important to vertical jumping performance, may indicate that there is a technique or skill component to vertical jumping, rather than just leg power(32). If this is true then the development of a motor pattern for V.J. will also be a factor affecting performance in V.J. testing of athletes

In relation to the specific composition of muscle fibres, it has been suggested that athletes with a well developed alactic or anaerobic power capacity will generate more power than athletes with a high aerobic power capacity.(11,26)

Methods of Developing Muscular Power (V.J.)

As has been mentioned already there has been many different methods and training techniques utilised in various research studies investigating the development of explosive leg power. Resistance training is a common term for many different types and variations of exercises using variable resistances which overload the musculature to provide a training effect(21). Plyometrics are a training technique which utilise the stretch shorten cycle (S.S.C.) to produce energy for dynamic muscle contractions, and are said to be vital to the optimal development of muscular power. Other forms of training commonly used to develop V.J. include various combinations of resistance training and plyometrics (1,2,4,22), short sprints, towing sleds, maximum vertical jumping, medicine ball drills and others which will be mentioned later.
In his article on maximising power development, Lyttle (21) summarises the various techniques used to develop explosive power, all of which are utilised in the various studies discussed in this review;-

1) Traditional heavy weight training.
2) Explosive light weight training.
3) Plyometrics.
4) Combined weights and Plyometrics.
5) Maximal power training.

There have been numerous studies investigating the effects of weight training on power development (1,2,4,9,13,23,31), and plyometric training (1,2,6,7,9,13,18,22,31), while limited research has been carried out investigating the combined effects of plyometric and weight training on vertical jump ability (1,2,4,9,13). Much of the research to date comes from authors who use subjects who come from jumping oriented sports (volleyball and basketball), and apply the results of their research directly to these sports. However these training techniques can be applied to many sports which require high levels of explosive leg power as a major physiological component for optimal performance.
O' Shea (1976) cited in (22) claims that recent innovative training techniques like plyometrics may have been responsible for the continuous improvements observed in today's athletes. Other studies have suggested that plyometric training techniques used by themselves or in conjunction with resistance training is no more effective than just resistance training techniques alone (31). Most available literature examining muscular power development has dealt with the development of lower body power. Therefore the relative success of upper body power training is unclear, and its effect on lower body power development is still relatively unknown. The lack of research in this area has been attributed to the difficulty in accurately assessing upper body power and performance, and also the fact that the majority of sports are lower body dominated (18). It has been shown however that upper body movements and trunk stability are important factors in the development of explosive power and V.J..
As vertical jumping is involved in most sports to a greater or lesser extent, most coaches and conditioners of team sport athletes would employ some or all of these techniques alone and in combination with each other depending on the demands of the specific activity and the phase of training. However the specific requirements of the sport should be kept in mind to determine the appropriate training techniques to apply.

It is difficult to compare and contrast the results of the various studies which have been published, as they all vary greatly in the application of training techniques, duration of research, testing procedures utilised and the general experimental design. Wilkes (30) refers to several limitations in applied strength training research which could easily be applied to the majority of the available literature on power training research, which influences the validity of the conclusions drawn from the research. These will be discussed briefly later on and should always be taken into consideration when reading a journal article or scientific research article.

Factors Affecting Development of Vertical Jump

There are several factors which influence the success of a program to develop lower body muscular power, both in the short term and over a longer period of athlete development. Vertical jump ability depends on the capacity of the alactic energy system to produce maximum amounts of force as quickly as possible. It has been shown that any aerobic type endurance training or repeated exposure to aerobic type activities produces changes to the overall aerobic energy system. These changes have been shown to have a negative effect on anaerobic and alactic power production capacity.(12).Therefore concurrent training of both energy systems interferes with the development of each of these systems individually(12).Coaches and conditioners of team sports such as basketball, hockey, soccer and the football codes, need to address this problem and design the training program to minimise the negative effects of concurrent aerobic and anaerobic training.

The specificity of the movement patterns in the sporting performance compared to the movements required in a vertical jump, will also affect the ability of an athlete to V.J. successfully. ie If the athlete is normally required to jump from one foot using a run up then a two footed standing vertical jump may not be an accurate test of jumping ability or muscular power(32). Similarly if the athlete has to hold a ball or piece of equipment in their hands while executing a skill, a standard vertical jump may not accurately reflect their V.J. ability.

The overall volume of jumping performed by the athlete in training and in competition will influence the development of 'jumping technique', and the efficient use of a S.S.C. to produce a good V.J. performance. It has been suggested that the utilisation of the energy available in an S.S.C. can be trained for, but that it is a separate strength quality in itself, unrelated to other qualities.(32) Specific jump training and depth jumping techniques have been developed for training of this specialised strength quality.

Continual development and maintenance of general and specific strength is important for the long term development of vertical jump performance(5). Therefore periodisation of the overall training program is vital to, maximise the desirable training effects and to minimise the interference of other negative training effects(21).

Possible Explanations For Differences In V.J. Performance Among Team Sport Athletes

As mentioned previously there is limited research available investigating this area, however it is possible to examine the physical and physiological demands of various sporting activities and to attempt to predict the effects of these upon a program designed to develop vertical jump ability.

Research has shown international volleyball players to rely primarily upon their anaerobic energy system to supply energy demands during a match(11).

However matches can last up to two and a half hours, therefore some aerobic component must be present as well. Fox and Mathews in(25) state that volleyball is 90% anaerobic and 10% aerobic, whereas more recent research suggests that it is more like 50% aerobic, 50% anaerobic (10% lactic and 40% alactic)(25).
Elite volleyball players typically show muscle fibre percentages of around 52-60% Fast Twitch muscle fibre composition, which compare favourably to samples from elite level sprinters and jumpers (45-80%FT) (11).
Typical VO2max. scores for elite volleyball players are around 50-60 ml/kg.min.-1 for males, 40-50 ml/kg.min-1, for females(11). These scores are not that different to the scores Soccer players (53-67 ml/kg.min-1), Basketball players (45-55 ml/kg.min-1), and football players (43- 55 ml/kg.min-1)(11).
Elite volleyball players spend far more time in training developing anaerobic power than is spent doing slow continuous aerobic work. Whereas elite basketball, football, hockey and soccer players would spend a majority of their time in training developing the aerobic qualities of their sports. As already mentioned concurrent training for strength/power and endurance are not compatible and negatively affects the development of each quality individually(12).
For elite level volleyball players training's and competitions primarily compose of short duration, high intensity work efforts interspersed with relatively long rest periods, so lactate build up is not intense. High Repetition jumping is also a characteristic of training and competition for volleyball players, who make use of several different jumping techniques, during spiking and blocking.
Other team sports such as basketball, the football codes, soccer and hockey which are mentioned throughout this review are all predominantly aerobic in nature, or more so than volleyball. Work periods are usually longer than rest periods and the overall distance covered in a game is much greater than for volleyball players. This is reflected in the type of training these athletes commonly do. Basketball players, like volleyballers would do lots of jump training, but basketball requires the athlete to carry a relatively heavy ball, often take off one foot and often without full use an effective arm swing. These athletes are generally exposed to less jumping in training and competition, compared to volleyball players. As mentioned previously basketball requires a much larger aerobic component, thus producing a training conflict between power and endurance. Athletes in other activities such as soccer and hockey, where jumping is not a primary skill, develop leg power specific to their sport through exposure to intense competition and various training techniques as described briefly earlier on. Therefore a standing vertical jump test may not be the best indicator of leg power for these athletes.
Schmidtbleicher (1990) in (32) has divided S.S.C. movements such as jump take offs into two categories according to ground contact times;-

-long S.S.C. - greater than 0.250 secs. eg. volleyball block jump
-short S.S.C. - less than 0.250 secs. eg. high jump take off.

He claims that it is possible for an athlete to excel at long S.S.C. type activities without being proficient in short S.S.C. movements and visa versa. This suggests that jumping abilities are extremely sports specific. Young (32) suggests that standing vertical jumping as seen in a volleyball block jump (long S.S.C) may be dependant on different strength qualities compared to a lay up take off in basketball, off one foot, which involves a short ground contact time and a relatively small knee bend. Young also mentions something in his article regarding the differences in 'jumping skill' between different jumping techniques, which he refers to as a 'critical timing' (C.T.) C.T. relates to the timing of the sequencing of the movements required to execute a skill. ie a high jumper must

develop critical timing to transfer horizontal velocity into vertical height, and this is a major part of the skill.

Limitations of available literature

As with most scientific investigations there are various limitations which will effect the validity of the results and the application of these results to populations outside of the specific experimental groups. Available literature investigating the present topic is inconclusive, inconsistent and relatively hard to come across.
There have been numerous studies which have investigated leg power in athletes from various sports, in an attempt to examine responses to training and competition, many of which have used vertical jump to test their protocol. However very few studies have taken a broad cross section of elite athletes from lots of different sports to compare them in all areas relating to explosive leg power and jumping abilities. Research such as this could help investigators understand the reasons why differences exist between athletes in vertical jumping, and also how to test more accurately the specific qualities exhibited after many years of specialised training.
Generally the available research which relates to this topic has its limitations in that there is no standardisation of the experimental procedures and the testing protocols. Tests which have been shown to be poor indicators, are still used to get results and to prove what they set out to achieve.

Wilkes (30) refers to several limitations in applied strength training research which can be applied to many of the research studies published in applied power training research as cited throughout this review. These limitations greatly influence the validity of any conclusions drawn from the results. Below are some of the limitations outlined in his article;

1) Short study periods;- Applied studies are typically short term, 6 - 8 weeks generally which is not recognised as being long enough to draw conclusions from. Repeated observations or long term programs may achieve different results which are generally far more reproducible. Of the articles reviewed here the shortest study was 3 weeks, and the longest was 12 weeks (7).

2) Unrepresentative subject groups;- The experimental design of most studies uses too few subjects to be able to generalise from the results. Subjects may be inexperienced or elite, and will vary in their response to exercise. Results of tests and training methods on elite athletes cant be transferred across to non elite athletes and visa versa. Many of the studies did not appear to consider the training backgrounds of the subjects involved and the types of activities they were involved in. Another factor which should also be considered if all contaminating elements are to be eliminated is that of performance enhancing drugs. Not one of the research studies mentioned anything about pre or post testing their subjects for drugs, which could greatly affect the results of the study.

3) Absent or inadequate comparison groups;- Some studies often neglect a control group to compare the effects of the independent variable, therefore the dependant variable could have been influenced by anything. It is also questionable as to whether the researchers ensure that subjects in each experimental group are equally distributed in relation to training background, strength levels, etc.

4) Inadequate dependant variables;- Many studies implement poor testing procedures to assess the effect of the independent training variables(14). V.J. has been shown to correlate strongly with measures of muscular power, but some of the other tests utilised in the literature under review here have been shown to be poor measures of testing muscular power of the lower body. ie. 50 yard dash (14), isokinetic tests of leg strength(6,31), and standing broad jump(4).

5) Inadequate Independent Variables;- This does not allow for ease of replication of the study by other researchers. Many of the studies here had vastly different types of exercise prescriptions and were unspecific as to the volume, intensity, tempo and technique required for performance.

6) Interference via strength measurement;- This is where periodic testing of strength levels becomes part of the training regime. This applies to power training research equally as much as strength training research.

Due to the general lack of research investigating this area, for the purpose of this review I have had to identify recognised factors which affect V.J. ability, and attempt to compare these with physical and physiological characteristics of elite volleyball players and elite performers in other team sports. There was insufficient data to be able to concentrate on any sports in particular apart from volleyball and basketball, for which there seemed to be the majority of vertical jump research.
Overall the major limitation with regards to the current research in this area is that there appears to be a major shortage of studies comparing normative data on vertical jump performance in attempt to explain differences in specificity of athletic ability.

Conclusions and Implications for Training

Due to the limitations and discrepancies within the research designs which do exist and the apparent lack of studies which have investigated this topic, in general it is very hard to draw any solid conclusions from this review. However there did appear to be trends and similarities between the available literature which suggested that elite volleyball players on average tended to have higher vertical jump scores when compared to some other team sports(25). There was very limited normative data available to me for many team sports which made comparisons very difficult.
Available literature supports the idea that different jumping styles and techniques exhibited between various sporting activities require very different strength properties and motor pattern development, for optimum performance (16,24,25,29,32). Throughout the literature there was strong evidence for the importance of the role of the arm swing(16), torso extension and head movements in V.J. performance, as well as the role of leg power in maximum extension(5,16,32).
Other factors affecting V.J. ability which were identified in the literature include the % of fast twitch muscle fibres (19,21,23,31), and high alactic power production capacity(11,26), motor unit activation and synchronisation and specificity of the movement pattern (23,26).
Upper body and torso strength has also been identified as a factor which affects vertical jump ability(5,8,26,32)
Exposure to high level explosive jump training was also identified as a factor which affected the athletes ability to make efficient use of the elastic and contractile energy available in a S.S.C. type contraction as seen typically in volleyball jump performance and in standing vertical jump performance.(26)

Athletes exposed to a greater volume of jumping and jump training should increase V.J. performance at a faster rate than athletes in non jump related sports.
Schmidtbleicher (1990) cited in (32) suggests that S.S.C. type contractions are a separate strength quality that can be divided into two categories, long and short. He states that they are developed independently of each other by specific types of training, and that an athlete who is at an elite level utilising one type of S.S.C., will not necessarily be proficient in performance of the other type of S.S.C. contractions.

There are many different ways to develop explosive leg power and therefore vertical jumping ability, which are all effective to some degree if used appropriately. The relative effects of resistance training (1,2,4,9,23,31), plyometric training (1,2,6,7,13,18,22,31), and various combinations of these modes (1,2,4,9,13), have been well documented.
When developing a program designed to increase leg power or V.J. ability it is important for coaches and conditioners to take into account the factors that affect performance of that specific type of vertical jump, the specific requirements of their sporting activity, and to develop the program around these.
It is apparent that jumping ability is highly specific, and therefore care needs to be taken when testing for leg power and vertical jumping ability using standard V.J. tests, to ensure that the test is sports specific and is testing what it is meant to be testing.
Another important factor affecting V.J. performance in the short term and in the long term, was that of an interfering effect of concurrent strength/power training and endurance training (12). This applies especially to athletes in sports which require high levels of explosive power as well as a high aerobic component. When designing a program to increase V.J. performance it is important to periodise it so that aerobic type training does not coincide or interfere with strength and power training phases.

Due to the lack of available research it was only possible for me to propose possible explanations for the apparent differences exhibited by various team sport athletes in V.J. ability, as shown in the research. By comparing the known physical and physiological effects of long term exposure to certain modes of sports specific training and competition, to the factors which affect V.J. ability and development of V.J., we can attempt to do this.
Overall the literature suggests that the differences in V.J. ability exhibited may reflect the highly specific nature of different jumping styles and techniques, which make certain jumping techniques specific to some sports and activities and not to others.
Therefore current tests of leg power and jumping ability should be reassessed as to their actual validity, and new testing protocols developed.
It was also suggested throughout the literature that vertical jumping in its many forms requires a skill component of its own, therefore non jump trained athletes will suffer in vertical jump performance until they have developed a motor pattern for the movement. Jump trained athletes however would not need to go through such a learning curve.
In closing, it would appear obvious that more research into this area is required before any conclusions can be drawn. Presently we can only make educated guesses and hypothesises to why these differences exist in jumping ability. Until we know more about this area, care should be taken to identify the specific requirements of the sport, skill or activity and to design optimum training methods, specific to the development of these requirements.

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