Chapter 5

DISCUSSIONS

This chapter will be divided into two major parts. The first part will discuss the results of this study and can be further divided into 1) test-retest reliability analysis; 2) validity; 3) discriminant analysis and 4) practical applications. The second part of this chapter will summarize the entire study. Conclusions will then be drawn and finally, recommendations for further research will be suggested.

5.1 Discussion

The main purpose of this study is to establish a test to measure human repetitive speed jumping ability to a sub-maximal height and to study the characteristics of this type of movement. The process of establishing the speed jump test involved claiming its test-retest reliability and predictive validity. The characteristics of this type of SSC movement are studied through correlation analysis with six variables measured from three speed strength tests.

5.1.1 Test-retest Reliability

The test-retest reliability of the speed jump test is examined using Cronbach’s alpha coefficient, Pearson’s Product Moment correlation coefficient and Student’s t-Test.
The Cronbach's alpha coefficient computed for speed jump test indexes across all 2, 3, 4, and 5-repetition Speed Jump Test were 0.909, 0.918, 0.949 and 0.949 respectively. All these coefficients met the requirements suggested by Pallant (2001) where the coefficient was suggested to be at least 0.7. This result indicated that the 2, 3, 4, and 5-repetition Speed Jump Test were internally consistent.

The Pearson's correlation coefficients computed for the speed jump indexes measured during the first and second sessions were 0.85, 0.891, 0.918 and 0.907 across all the 2, 3, 4 and 5 repetitions speed jump tests respectively. This range of correlation coefficients is statistically significant at the level of \( p < 0.01 \) and fulfill the required reliability measures as suggested in Atkinson and Nevill (1998). These indicate that all the 2, 3, 4 and 5 repetitions speed jump test have high relative reliability where it can consistently distinguish between individuals in a particular population.

Student's \( t \)-Test performed revealed that there are no significant differences between the speed jump indexes measured during the first and the second session. This indicates that there is no statistically significant systemic bias between the speed jump indexes measured during the first and second session. In other words, the speed jump index is a stable measurement variable that is capable of giving consistent reflective measure of speed jumping ability.

5.1.2 Validity

Another primary purpose of this study was to establish the validity of the speed jump test. Predictive validity was our major concern in this context and it was established by studying the relationships and common variances of the speed jump
test index and three general physical characteristics, leg speed, leg power and reactive strength. Pearson’s correlation coefficients were computed to validate the speed jump test as a measure of leg speed, leg power and reactive strength. Besides, another purpose of this study was to further analyze and study the characteristics of the repetitive speed jumping ability through these correlation analyses between speed jump index and 6 performance variables that were derived from the three main physical characteristics of leg speed, leg power and reactive strength. These six variables are F10m, L30m, 40m, VJH, CDJH and BDJ$_{im}$.

Among the first three performance variables, 40m was a general measure of leg speed. F10m was aimed at measuring the initial acceleration phase in sprint running whereas L30m was the representative measure of maximal velocity maintenance phase (Baker and Nance, 1999; Mero, Komi and Gregor, 1992; Young, McLean and Ardagna, 1995). VJH was the measure for leg power (Abernethy, Wilson and Logan, 1995; Adams, O'Shea and Climstein, 1992; Harman et al., 1991; Johnson and Bahamonde 1996) whereas CDJH and BDJ$_{im}$ are the representative measures for long and short SSC respectively (Newton, Kraemer and Hakkinen, 1999; Schmidtleicher, 1992; Young, Pryor, and Wilson, 1995; Young, Wilson and Pryor, 1999).

The 3-repetition speed jump test index correlated significantly with 40m ($r = -0.445; p < 0.05$) and VJH ($r = 0.446; p < 0.05$) but not both countermovement reactive strength ($r = 0.325$) and bounce reactive strength ($r = 0.235$). These results indicated that the 3 repetitions speed jump test is a valid test of leg speed and leg power but not reactive strength. It seems reasonable too to assume that the ability to jump repetitively to a sub-maximal height as fast as possible is determined primarily
by how fast the lower limb can move and how much force it can exert in the shortest time possible. The following discussions on the relationships between speed jump index and each of the speed strength measures will further explain the issues of validity in this speed jump test. The remaining variability of the speed jump test was however, unaccounted for by these variables. It is possible that the remaining variability of the repetitive speed jumping ability would be accounted for by either other known physical characteristics such as dynamic balance, or physical characteristics that have yet been identified.

The correlation analysis performed on the speed jump index and another two performance variables that were derived from the leg speed measures (40m), F10m and L30m further aided in validating the speed jump test. Despite the significant correlation between speed jump index and leg speed, F10m however, did not show any significant relationship with the speed jump index. L30m, on the other end, has the highest zero-ordered correlation with the speed jump index at \(-0.520\) (p < 0.05). This indicates that the speed jump index actually shared a larger part of common variances with the L30m, and the repetitive speed jumping ability can be better accounted for by the maximal speed maintenance phase in sprint running where the SSC is believed to play a significant role (Baker and Nance, 1999; Chelly and Denis, 2000; Kuitunen, Komi and Kyrolainen, 2002; Mero, Komi and Gregor, 1992; Young, McLean and Ardagna, 1995).

Chelly and Denis (2001) investigated the relationship between leg power and hopping stiffness with sprint running performance in teenage runners. They reported that leg stiffness measured from a hopping test was correlated significantly with the maximal running velocity phase in sprint running. It was concluded that it is during
this phase that the knee and ankle joint stiffness play a major role in maintaining the maximal running velocity by transmitting the work done by the hip extensors better and therefore propelling the body forward more effectively. This minimized the amortization phase and therefore the ground contact time. Hence, it is reasonable to suggest that the SSC also plays a significant role in the speed jump test by regulating the stiffness of the joints to absorb eccentric power and transmitting it as fast as possible vertically to minimize the amortization phase and therefore the contact time. Their conclusions further explain the characteristics of the repetitive speed jumping ability in relation to leg speed.

Ankle and knee joint stiffness have also been reported to increase with running speed in other studies (Kuitunen, Komi and Kyrolainen, 2002; Stefanyshyn and Nigg, 1998). Kuitunen, Komi and Kyrolainen (2002) concluded that in sprint running, the spring-like behavior of the leg might be adjusted by regulating the stiffness of the knee joint whereas the ankle joint stiffness remained the same. Stefanyshyn and Nigg (1998) reported that the ankle joint stiffness increased with the running speed. Farley and Morgenroth (1999) however revealed that the primary mechanism for leg stiffness regulation during human hopping task was by regulating the ankle joint stiffness. The appropriate mechanism that plays the major role in stiffness regulation during repetitive speed jumping was however, unable to be concluded in this study. However, due to the large variation in the individual contact times in this study, it is believed that both the knee and ankle joint stiffness are the limiting factors for the repetitive speed jumping ability. This is because the ground contact time of several subjects fell within the short SSC range while others fell within the long SSC range. These results further validate and explain the characteristics of the SSC in repetitive speed jumping.
The relationship between speed jump index and leg power has to be interpreted with caution because the speed jump index use in this study was a derivation of vertical jump height since the pre-determined height was calculated by taking 80% of the vertical jump. Nevertheless, SSC activity has long been accepted to result in augmented power production (Komi, 1984). The impact of power as a performance component on the performance of SSC is however, never been studied.

Cronin, McNair and Marshall (2000) investigated the role of maximal strength and load on initial power production during concentric and SSC activity. Their results indicated that maximal strength augment the initial 200ms of SSC performance across all the external resistance tested. They suggested that this was because stronger muscles were able to generate a higher active state at the inception of the concentric phase. This can be attributed to the force production capability of the contractile, series elastic and parallel elastic components. They also found out that for SSC activity of short duration, greater maximal strength resulted in greater instantaneous power production. Therefore, the role of power in augmenting SSC activity should be similar since power equals the ability to generate force as fast as possible. It is believed that power augments SSC activity by enhancing power absorption and generates higher active state. (Cronin, McNair and Marshall, 2000; Cronin, McNair and Marshall, 2002). Besides, the ability to recruit more muscle fibers will increase the stiffness value of the tendomuscular complex and thereby allowed the work done during the eccentric phase to be transmitted as fast as possible during the concentric phase (Viitasalo, Salo and Lahtinen, 1998).

The low and insignificant correlation between the speed jump index and both countermovement and bounce reactive strength in this study is somewhat
unexpected. This might due to the limited number of subjects in this study. I certainly am not suggesting that there should be a significant relationship but I thought the correlations could be higher should there be more subjects. Besides, the 25cm dropping height used in both the test to accommodate the subjects age and fitness level in both the countermovement and bounce reactive jump tests might be too low to induce an optimal reactive jump height.

However, it is also possible that the results indicated that the SSC activity in the repetitive speed jumping is a different performance component from those of the long and short SSC, as reflected by the countermovement drop jump height and bounce drop jump index respectively. This is because of the fact that the SSC activity in speed jumping correlated better with the SSC activity in sprint running suggest that the speed jumping requires higher level of tendomuscular stiffness as compared to both the long and short SSC.

Arampatzis et al. (2001) investigated the influence of leg stiffness on myodynamic jumping performance. Their subjects were required to perform a series of drop jump from different heights of 20, 40 and 60cm. They controlled the leg stiffness through verbal instructions. The instructions given to the subjects were “jump as high as you can” and “jump a little faster than your previous jump”. The jumps were performed at each height until the subjects could not achieve a shorter contact time. The data was divided into five groups where group 1 was made up of the longest ground contact time times of each subject and group 5 the shortest. They concluded that there is an optimal stiffness value for the lower extremities to maximize mechanical power. This will lend support to our notion that the SSC
activity is task dependant where the stiffness of the leg was adjusted to accommodate the demand of the task.

In addition, the speed jump test in our study did not require the subjects to jump to their maximal attainable height and therefore the subjects did not need to perform the rebound jump at the optimal leg stiffness value. Instead it is possible that they increase their leg stiffness value in order to perform the speed jumping as fast as possible. Therefore, it is suggested that one of the determining factors in performing repetitive speed jumping is the ability to increase lower limbs tendomuscular stiffness. However, the question of whether it is the tendomuscular stiffness of the ankle joint or the knee joint that determine the repetitive speed jump performance remains unanswered.

If this is the case, as what we believe, the use of long and short SSC to categorize SSC activity as suggested by Schmidtleicher (1992) would seems improper and insufficient to characterize all the different types of SSC since the ground contact times in our study suggested that the SSC activity should be task dependant and not ground contact time dependant. Our subjects' contact times had a wide range from as low as 168ms, which should be categorized as short SSC to 475ms, which should be categorized as long SSC. These results imply that at 80% of their maximal vertical jump height, some subjects performed the repetitive speed jumping as a short SSC activity but to others, it was more of a long SSC activity. If this is the case, then how should the repetitive speed jumping be categorized (a short SSC activity or a long SSC activity)? And how should we train for this type of SSC performance (repetitive speed jumping ability) if we are to train according to contact times as suggested by Schmidtleicher (1992)?
The fact that our results suggested that the SSC activity is actually task dependent has given us a clearer picture on what has long been debated about, the mechanisms underlying SSC performance enhancement. Our results imply that both the time to build up active force state and elastic recoil play a major role in SSC performance. Their role in augmenting performance is however, task dependent. In task such as countermovement jump and countermovement drop jump that are characterized by larger angular displacement at the knees and longer ground contact times, time to build up active force state will play a major role since countermovement with a longer ground contact times allows the extensor muscles to build up a higher active state and force prior to jumping. Besides, a longer ground contact time will result in a longer stretching (eccentric) phase and as a result, the cross bridges in muscle fiber may be detached and loose their elastic potential. We certainly do not deny the contribution of elastic recoil but we conclude that in this type of SSC activity, time to build up active state will play a more important role as compared to elastic recoil although elastic recoil do play a role. This is further supported by researches that reported high leg extensor strength qualities requirements in this type of SSC activity (Young, Wilson and Byrne, 1999).

In task such as bounce drop jump, where the knee angular displacement is small and ground contact time is short, elastic properties will play a more significant role than the time to build up active state and force. This is because a short contact time limits the time available to build up active state and force. In addition, shorter ground contact time will prevent the cross bridges in the muscle fiber to detach and lost their elastic potential. It should be clear now that a different SSC movement will require a different combination of mechanisms to enhance performance, with each of them playing a major role during different SSC activities.
In addition, our results on the task dependant characteristics of the SSC activity are very much in line with the results in a study conducted by Finni, Ikegawa and Komi (2001) recently. In their study, the subjects were required to perform unilateral counter-movement jumps and repeated drop jumps with maximal and submaximal loading conditions. They suggested that the benefits of the stretch-shortening cycle muscle function might come through different interactive mechanisms that may be task specific.

Therefore, these findings will also lend support to the notion that all the three types of reactive jumps are of different performance components. At one end we have counter-movement drop jump where maximal height is of major concern and at the other end we have speed jump where speed is of major concern. Thus, the use of reactive strength or simply reactive ability is both not specific enough and insufficient to describe the three different performance component.

The ability to perform countermovement drop jump is largely dependent on the ability to generate high active state and force and maximal strength. Thus, it should be proper for this ability to be called reactive strength. At the other end, the ability to perform reactive jump as fast as possible (speed jump) will largely depend on the ability to induce a high leg musculo-tendinous stiffness value and speed. This type of performance component should be called reactive speed. As for bounce drop jump, which demands maximal height to be attained in the shortest time possible, it should be proper to call this ability reactive power since it requires an optimal amount both mechanisms.
5.1.3 Discriminant Analysis

It is believed that training age will be able to differentiate performance level of this group of basketball player. There have been reports on increment in anaerobic capacity with basketball training (Hoffman et al., 1991; Tavino, Bowers and Archer, 1995). Hence, comparison was made using t-test for the more and less experienced-training group. The speed jump index of the more experienced-training group ($S > 2$ tr yrs) was shown to be significantly higher than those of the less experienced-training group ($S < 2$ tr yrs) indicating that the speed jump test is valid and able to differentiate between different performance level in adolescent basketball players.

5.1.4 Practical Applications

Apart from claiming consistency and relative reliability for the speed jump test, the results are also in support of the procedures used in this study. Practically, clear instructions and one practice trial given before the administration of three trials are enough to reduce variances caused by individual’s learning curve. In addition to this, the use of the result from the best trial out of the three trials can be considered both consistent and relatively reliable.

Another problem that is yet to be resolved is the number of repetitions to be administered in a speed jump test. Correlational analysis between the 2, 3, 4, and 5 repetition speed jump test with the speed strength measures revealed that the use of 3-repetition is ideal for the administration of the speed jump test since it correlated most significantly with leg speed and leg power, which is the performance variable that mostly characterizes the repetitive speed jumping ability. It has also been
proven to be able to provide consistent results and to distinguish between individuals in a particular population.

Hence, it is proposed that in future, the measurement of the repetitive speed jumping ability using the speed jump test should employ a 3-repetition speed jump test protocol, with clear instructions, demonstrations and one practice trial before the three measuring trials. The result will be selected from the best trial out of the three trials as a reflective measure of the repetitive speed jumping ability.

The establishment of this test will enable coaches and practitioners to specifically identify strengths and weaknesses in performance. The division of three reactive abilities into reactive strength, reactive power and reactive speed better characterized the different types of SSC activities. This allows specific program to be drawn to suit specific needs and weaknesses.

5.2 Summary

The purpose of this study was to measure and study the characteristics of adolescent basketball player repetitive speed jumping ability to reach a sub-maximal vertical jump height. It was also one of the purposes of this study to develop and propose a test that measures this ability and to examine its reliability and validity. The reliability was studied by comparing the mean scores of the subjects in the speed jump test in two different sessions organized over two alternate days with one day of rest in between. The predictive validity and the characteristics of this ability were examined by studying the relationship of the speed jump test index and various speed strength measures.
The hypotheses tested in this study were that of there would be no significant differences between the speed jump test index in the first and second session; there would be no significant differences between the speed jump index of the experienced-training group and the less experience-training group; and there would be no significant relationships between speed jump index and leg speed, acceleration phase in sprint running, maximal velocity maintenance phase in sprint running, leg power, countermovement and bounce reactive strength. In addition, this study also addressed questions of which would be the ideal repetitions range for speed jump test and the characteristics of repetitive speed jumping ability. The results of this study are summarized as follows:

1. There were no significant differences between the mean speed jump index measured in the first and second session.

2. There were significantly high correlations between the speed jump index measured in the first and second session.

3. The speed jump index using a 3-repetition protocol had the highest zero order correlation with both speed and power.

4. The speed jump index of the higher training age group were significant higher than the speed jump index of the lower training age group.

5. There were significant correlations between the speed jump index and the 40-meter dash time.

6. There were significant correlations between the speed jump index and the last 30-meter time in 40-meter dash.

7. There were no significant correlation between the speed jump index and the first 10-meter time in 40-meter dash.
8. There were significant correlations between the speed jump index and power.

9. There were no significant correlations between the speed jump index and both the countermovement and bounce reactive strength.

5.3 Conclusions

Several conclusions on the speed jump test and its characteristics could be drawn based of the findings of this study and are listed as follows:

1) The speed jump test is a reliable and stable test.

2) The speed jump test is a valid test to measure leg speed and power.

3) The 3-repetition speed jump test protocol is the ideal protocol to be used in testing repetitive speed jumping ability.

4) One practice trial and three test trials are enough to bring out the best result from the subjects.

5) The selection of the best results for analysis is able to give consistent and reliable results.

6) The speed jump test is able to differentiate between different levels of performance.

7) The counter-movement drop jump, bounce drop jump and speed jump could be three different performance components.

8) The underlying interactive mechanisms in SSC activity could be task dependant and therefore, the muscle function and characteristics during different SSC activity could be task specific.

9) Different force enhancement factors will play their part in different SSC task.
10) Time to build up active force level in the muscle could be the major contributor for force enhancement during SSC activity where maximal jumping height is of major concern, such as during the counter-movement drop jump.

11) Elastic properties of the muscle could be the major contributor for force enhancement during SSC activity where both maximal jumping height and minimal ground contact time are important, such as during the bounce drop jump.

12) Leg stiffness plays a major role in SSC activity where speed is of major concern (low ground contact time), such as during the repetitive speed jump.

13) Reactive strength refers to the ability to reactively jump as high as possible without taking the ground contact time into consideration.

14) Reactive power refers to the ability to reactively jump as high and as fast as possible.

15) Reactive speed refers to the ability to jump reactively as fast as possible without the need to reach maximal attainable height.

5.4 Recommendations

Based on the current study, several recommendations has been suggested for future research on speed jumping ability and are listed as follows:

1. Study the repetitive speed jump test and reactive speed ability in other groups of subjects, such as adults and female adolescent, different level of athletes and sedentary.

2. Establish norm values for speed jump test.
3. Examine the ability of the speed jump test to detect changes in performance after a period of training.

4. Further explore the different characteristics of speed jumping through correlation analysis between other performance variables, such as maximal strength, running up jump, one or two legged jumps and other performance characteristics that haven’t been included in this study.

5. Investigate the underlying mechanisms for time to build up active force level, elastic properties and leg stiffness.

6. Examining the relationships between reactive strength, reactive power and reaction speed if they are mutually exclusive and if training for one will have an effect on the others.

7. Study the trainability of the speed jumping ability.

8. Study and compare the speed jump test on athletes from different sports that may have different types of force generation techniques and characteristics in jumping. For example, basketball and volleyball players.