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New jump test to predict sprint speed

Bachelor of Science in Biomechanics

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Abstract

Sprint speed is an important component in many different field sports and therefore vital to assess. The measure of sprint speed is often more difficult than the measure of jump ability. For these reasons the purpose of this study has been to develop and evaluate a new jump test protocol for prediction of sprint speed.

Twenty male athletes performed two test sessions, the first included sprint and jump assessments and the second session only jump assessments. The new jump test protocol was a single leg horizontal drop jump (SHDJ), kinematics and kinetics variables were collected using a force plate and tape measure. The validity of the test was investigated using Pearson's correlation and linear regression, and the reliability was examined using coefficient of variation (CV), intraclass correlation (ICC), and percentage change of the mean.

Significant correlations were found between all sprint times (5-25m) and jump distance divided by height ($r = -0.44$ to -0.65, $p < 0.01$), with the highest correlation found for the 10m sprint time. The combination of the jump distance divided by height of the subject and the horizontal ground reaction force explained between 50-72 % of the variance associated with sprint performance over the different distances. The best intra- and interday reliability was found in jump distance with a within-day CV of 1.3%, test-retest CV of 2.3 %, change in mean of 0.43 % and an ICC value of 0.95.

To improve the validity of the new jump test in predicting sprint speed, the landing distance needs to be controlled and standardized to a better extent.

It can be concluded that the intra- and interday reliability the jump distance from the SHDJ test was equal and in a lot of circumstances better than other tests of a similar nature reported in the literature.

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1. Introduction

Speed is a prerequisite to success in many sports: being faster allows the athlete to move earlier into situations that enable an advantage over their opponent. Maximum running speed and acceleration are important components in many different field sports (Bangsbo et al., 1991; Deutsch et al., 1998; Meir et al., 2001). The importance of maximum speed is generally accepted to be smaller than having a good acceleration because field sport athletes almost never have the distance during one sprint effort to reach top speed (Reilly & Borrie, 1992; Reilly, 1997). Penfold & Jenkins (1996) also find that quickness over the first few steps of a sprint is vitally important during a game.

Strength and conditioning practitioners spend a great deal of time writing programmes to improve the performance of their athletes. There is no doubt that the quality of these programmes will be improved by the understanding and utilisation of various assessment strategies. Better assessment and interpretation should result in better individualised programmes.

In terms of assessment, it is often more difficult to measure an athletes sprint speed than to measure his jump ability. Therefore many trainers and coaches use the performance of a jump as a predictor of the athletes sprint speed ability.

1.1. Purpose

The purpose of this study was to develop and evaluate a new jump test protocol for prediction of sprint speed.

1.2. Objectives

The objectives for this study were:

- to develop a new jump test protocol for sprint speed prediction.
- to determine the correlation between sprint speed and the kinetics and kinematics variables from the jump test.
- to perform a regression prediction analysis for the sprint times.
- to determine the intra- and interday reliability of the kinetics and kinematics variables from the jump test.

2. Literature review

This review of literature is divided into three parts; sprint running, jump assessments and statistical analysis. To be able to develop a new jump test protocol to predict sprint speed a knowledge of sprint running is essential. The investigation of what tests are used today and their relationship with running is also important. Finally, to make a correct evaluation of the new jump test knowledge of the right statistical tools to use is needed; the last part of this review discuss this important subject.

2.1. Sprint speed

Sprint speed is dependent on two main areas; biomechanics and physiology (Figure 1). Describing these areas gives the essential understanding of what abilities are needed in order to be a well performing sprinter.

The technique and components are to some extent different between track and field running and the running performed in field sports. For example this difference may depend on differences in surface, shoes or running distance.

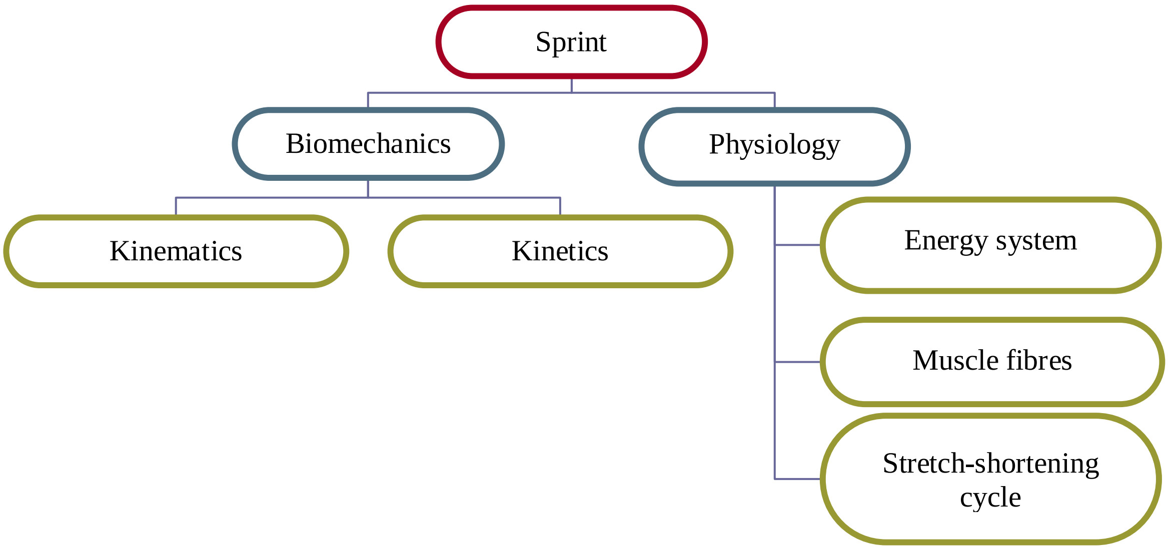

Figure 1: The components of sprint speed

2.1.1. Physiology

The physiology components reviewed are; the energy system, muscle fibres and the stretch-shortening cycle. These components was found to be most important by the authors of this report.

Energy systems

Energy is required in many types of processes in the human body, such as growth, repair, and molecular transport. All these processes receive their energy from one single molecule, ATP (Adenosine-Tri-Phosphate). ATP consists of an adenosine molecule and three (tri) inorganic phosphate groups.

The energy needed for these processes in the body is released from the ATP molecule through a process called hydrolysis. Hydrolysis is the reaction which occurs when ATP reacts with water leading to a split of the molecule. This results in the formation of an ADP (Adenosine-Di-Phosphate) molecule, a phosphate group and most importantly, the release of energy.

$$\text{ATP} \rightarrow \text{ADP} + \text{P}i + \text{Energy}$$

Following this reaction, the ADP molecule needs to be re-synthesized to the ATP molecule. This is occurs via a reaction called phosphorylation; meaning that a phosphate group is added to the ADP molecule.

There are three separate energy systems responsible for the resynthesis of ATP. A number of factors including intensity and exercise duration help to determine which of these three systems will be the primary contributor to ATP resynthesis during exercise.
(Wilmore & Costill, 2005).

ATP-PCr

This system is the first to kick in and, as the name implies, it consists of two parts that work more or less side by side. The first part involves stored ATP in the muscle cell, which can be used directly as an energy source. The second part consists of the breakdown of PCr (Phospho-Creatine), causing the release of a phosphate group and energy. The phosphate group and energy are then subsequently used to resynthesize the ADP molecules to ATP. The reaction occurs without the use of oxygen, therefore the ATP-PCr energy system is an anaerobic energy system.

Part one - the stored ATP in the muscle - only lasts for a few seconds. However together with part two of this system - the breakdown of PCr and re-synthesis of ATP - the system can deliver a significant amount of energy during 3-15 seconds.

(Wilmore & Costill, 2005).

The Glycolytic system

This system is the second fastest to kick in when energy is needed during exercise. It is based on the breakdown of glucose, of which carbohydrates form the greatest supply.

Glucose is transported by the blood to the muscle cells. In the cytosol of the cells the glucose is broken down though a process called glycolysis (which literally means breakdown of glucose), the end product of glycolysis is a molecule called pyruvic acid. Pyruvic acid is half of a glucose molecule; meaning that from one glucose molecule two pyruvic acid molecules are formed.

If the cell has enough oxygen, the pyruvic acid continues its way into the mitochondria of the cell and the oxidative system takes over. If that is not the case, the pyruvic acid will be converted into lactic acid. These two possible outcomes from the glycolysis have been labelled aerobic glycolysis and anaerobic glycolysis.

The contribution of the glycolytic system increases rapidly 10 seconds after the start of exercise and after 30 seconds it contributes the majority of the energy used.
(McArdle & Earle, 2000)

The oxidative system

If the supply of oxygen to the cells is substantial, as has been mentioned before, the pyruvic acid will go into the mitochondria and via two processes (Krebs cycle and the electron transport chain) create energy.
(Wilmore & Costill, 2005).

Jump and sprint assessments

In both jump assessments and sprint assessments (over 20-30 metres) the time taken to perform the activities is relatively short. For example, the jump test takes less than 1 second and the sprint test takes 4-5 seconds.
This means that ATP-PCr energy system is primarily responsible for providing the energy required during both jump assessments and sprint assessments over 20-30 metres. Subsequently, different energy systems cannot be considered as a factor that could potentially influence the results from these two types of tests.

Muscle fibres

The muscle fibre (cell) consists of functional units called sarcomeres. Each of these sarcomeres is composed of the myofibrillar proteins myosin (the thick filament) and actin (the thin filament) (McComas, 1996). The myosin protein consists of six polypeptides of which four form heavy chains and 2 form light chains (Scott, 2001). The actin molecule consists of two regulatory proteins and is closely connected to troponin and tropomyosin (McComas, 1996).

When the muscle fibre receives a stimulus from a motor neuron, Ca^{2+} is released from the sarcoplasmatic reticulum. The calcium then binds to troponin, and through tropomyosin exposes a binding site for the myosin head on the actin molecule.

If there is ATP present, the myosin head will attach to the binding site and pull the actin filament along the myosin filament and the sarcomere is shortened (Plowman & Smith, 1997).

Muscle fibres are generally accepted to be of two types; slow twitch (type I) and fast twitch (type II). Fast twitch fibres can furthermore be divided into fast twitch A and fast twitch B (McArdle et al., 1996; Lieber, 1992).

Slow twitch:

The slow twitch fibres contract slowly for two reasons; firstly due to the relatively slow activity of their ATPase (the enzyme that splits ATP) which makes the crossbridge turnover slow; secondly because the fibres have a relatively under-developed sarcoplasmatic reticulum. Slow twitch fibres have a very high resistance to fatigue due to the large and numerous mitochondria in the cell. This means these fibres primarily use the oxidative system for ATP resynthesis. Additionally their motor unit strength is low, which is due to the fact that the motor neurons attached to slow twitch fibres have a small cell body and stimulate relatively few fibres.

Due to the iron containing cytochromes these cells are red in appearance. The diameter of the fibres are relatively small, however there are plenty of capillaries within the structure.

The characteristics mentioned above make this fibre type very suitable for low intensity endurance activities. (Wilmore & Costill, 2005).

<u>Fast twitch A:</u>

This type of fibres can produce an explosive power, which is due to the large cell body of the motor neuron and also the high number of axons that can innervate a large number of muscle fibres.

The fast twitch A fibres can contract very rapidly, due to their ATPase making the crossbridge turnover fast, and also to their relatively high developed sarcoplasmatic reticulum.

The number of mitochondria in this kind of muscle fibre is moderately high, but the fibres rely mostly on the glycolytic system, and mostly the anaerobic glycolysis to resynthesize ATP.

These characteristics together make these fibres suitable for explosive work and exercises. (Wilmore & Costill, 2005).

<u>Fast twitch B:</u>

The fast twitch B is similar to the fast twitch A, with the difference that the oxidative capacity is lower, meaning the glycolytic capacity is even better for the fast twitch A and the fatigue resistance is lower.

This makes this fibre valuable in activities that need the highest force and power, but only for a very short time. (Wilmore & Costill, 2005).

The common muscle used for movement generally consists of a mixture of both slow and fast fibres, around 50% slow twitch, the other half is divided equally between the fast twitch A and B. However, this ratio can vary, which makes humans more or less suitable for different sports. (Wilmore & Costill, 2005).

As mentioned in earlier sections; the energy system used in jump and sprint (over 20-30 metres) assessments is the glycolytic system, involving primarily anaerobic glycolysis. These assessment both utilise highly explosive and rapid movements. Given this, it is reasonable to assume that there are similar muscle fibre types assessed in both a jump test and a sprint test (over 20-30 metres).

Stretch-shortening cycle

The different muscular actions are usually divided into concentric, eccentric and isometric. However, in reality a muscle action seldom fits purely into one of these categories, but instead a combination of them.

When looking at the normal muscle functions during for example walking, running or sprinting, the muscle is first exposed to the external force of the gravity which lengthens the muscle under active tension from the muscle (eccentric phase) and then subsequently the muscle contracts (concentric phase). This cycle, including the preactivation of the muscle before ground contact is called the Stretch-shortening cycle (Norman & Komi et al., 1979; Komi et al., 1984, 2000).

The Stretch-Shortening cycle (SSC) has a well know purpose, to increase the performance (muscle force) in the final part of the SSC (the concentric phase), for example the push off in running. This has been shown in isolated preparations with constant electrical stimulation (Cavagna et al., 1965, 1968).

The first explanation of this performance improvement was made by Cavagna et al. (1965), who suggested that the primary explanation for the phenomena was stored elastic energy in the muscle-tendon complex due to the eccentric phase. So far, this explanation has not been contradicted.

The stretching of the muscle-tendon complex

During the eccentric phase of SSC, the muscle-tendon complex is clearly stretched; however, there has been some discussion over whether the contractile unit of the muscle and the tendon change their length in phase. Hoff et al. (1983) and Belli & Bosco (1992) suggest that the contractile units of the muscle have the same length and Griffiths (1991) suggests that they are shortened, in the early phase of the eccentric phase, while the whole complex is being stretched.

Work done by Finni et al. (2001) demonstrates that the length relationship between muscle and tendon is a very complex matter. Furthermore Finni et al. (2001) states that there is a difference in the relationship between muscle and tendon depending on type of SSC movement. For example, the fascicle demonstrates minor length change in a countermovement jump compared to a drop jump.

Stretch-reflex

It is well recognized that a quickly imposed stretch of a human muscle-tendon complex leads to a number of reflexes shown on an electromyography (EMG).

The first EMG peak to be seen is the short-latency response, which is followed by the medium-latency response after. These two responses are sometimes referred to as M1 and M2 (Lee & Tatton, 1975). The origin of M1 is accepted to come from afferent inflow from Ia muscle spindle receptors mediated over a segmental pathway (Fellows et al., 1993). However, there has been a discussion about the origin of the M2 response, which is observed after M1. Grey et al. (2001) conclude that the M2 reflex is activated by group II muscle spindle afferents.

Voigt et al. (1998) conducted an EMG study where they investigated jump test called two-legged hopping. Their study showed that there are high stretch velocities in the early contact (eccentric) phase. The authors conclude that these velocities are sufficient for the muscle spindle to be activated.

Komi & Gollhober (1997) performed a study where they examined drop jumps from a number of heights. They established that the higher the jump (e.g. 80 cm) the more unclear the stretch-reflex response becomes. The authors suggest that the reason for this is decreased activity in the Ia muscle spindles and/or an increased inhibitory effect from e.g. golgi tendon organ and voluntary protection organs. The latter should be a protection against injury.

Komi & Gollhofer (1997) conducted a study where they assessed drop jumps from 60 cm. This study showed a sharp EMG peak after 40-45 ms post initial ground contact, this corresponds very well to the short-latency response (Lee & Tatton, 1975). The EMG peak is especially clear in the Soleus muscle.

<u>In which part of the SSC does the reflex act?</u>

The stretch reflexes are a very vital part in the stiffness regulation of the muscle-tendon complex (Hoffer & Andreasson, 1981), this implies a contribution to the muscle stiffness already in the eccentric phase.

The reflex response is delayed 45-65 ms after the initial ground contact. If one compares that time with the ground contact time of a marathon runner, which is approximately 250 ms, it is obvious that the reflex is acting in the eccentric phase (Nicol, 1991).
Luhtanen & Komi (1978) state that the ground contact phase is a function of the running speed. Meaning that in maximal sprinting (contact time of 90-100 ms) the net reflex contribution will occur in the end of the eccentric phase or in the early concentric (Mero & Komi, 1985).

The stiffness regulation of the muscle-tendon complex is an essential component of performance. The Range of Motion for the individual muscle is of course of high importance, but so is the stretch-reflex contribution during the eccentric phase.

Important components for performance

In order to have an effective SSC, Komi & Gollhofer (1997) have stated three factors that are important for the performance;

- Before the eccentric phase, you should have a well timed preactivation of the muscles.
- The eccentric phase should be rapid and brief.
- There should be an instant change from the eccentric (stretch) phase to the concentric (shortening) phase.

2.1.2. Biomechanics

The biomechanics of running involves describing the movement pattern (kinematics) of the athlete and the forces acting (kinetics) on the runner.

Kinematics

Kinematics is a description of movement and does not consider the forces that cause that movement.

Running speed

Running speed is dependent on 2 variables; the stride length and the stride frequency, the relationship is described by this simply equation: Speed = Stride length × Stride frequency. A stride in this matter is a half running cycle, e.g. from touchdown on the left foot to the next touchdown on the right foot. If an improvement in speed is required one or both of these factors need to be improved without a decrease of the other. (Hay, 1994)
The maximum running speed is determined by the amount of force applied to the ground rather than the rapidity of the limb movement. (Weyand, 2000)

Stride length

The stride length can be divided into 3 distances; takeoff distance, flight distance and landing distance. The takeoff distance is the horizontal distance between the centre of gravity and the takeoff foot. This distance is dependent on the position of the athlete’s body; the distance is greater during acceleration and smaller at maximum speed. The factors that determine the flight distance are speed, angle, height from the takeoff and the air resistance encountered in flight. The most important of these factors is the speed from takeoff, with the least important being the air resistance. The speed from takeoff is primarily determined by the ground-reaction forces exerted on the athlete. The smallest contribution of the three distances is the landing distance. It is the distance from the foot strike until the foot is directly under the centre of gravity. If this distance is too big, this will lead to a highly reducing horizontal force, which consequently will decrease the running velocity. (Hay, 1994)

Hoffman (1971) showed that there is a very close relationship between the stride length and the standing height of a sprinter, with the average stride length being equal to 1.14 times the height. Rompotti (1975) conducted a similar study with 32 students, with the result that stride length was 1.17 times the height. Both studies showed very similar result, independent of the level of athletes.

Stride frequency

The stride frequency is defined as the number of strides completed in a given time. The time it takes to complete a stride can be divided into the time the athlete has contact with the ground and the time in the air (Hay, 1994). In top-class sprinters the ratio between the two is around 2:1 during the first acceleration steps and between 1:1.3 and 1:1.5 when the athlete is running at maximum or near-maximum speed. (Housden, 1964; Atwater, 1981)

Ground contact time

The ground contact time is from this moment just called contact time (CT) and is the time that the athlete has contact with the ground during one stride. It has been showed that the fastest sprinters also have the shortest contact times (Mero & Komi, 1987; Mero et al., 1992). The contact time depends therefore on the velocity of the run and Coe et al. (n.d.) and Skripko (2003) reported both a CT of 101 ms for the running velocity of 8.9 m/s and 9.1 m/s, respectively. Bruggeman & Glad (1990) made a study on top sprinters with maximal running velocity from 10.20 to 11.60 m/s and had a contact time between 85 and 95 ms. Hunter et al. (2004) reported a contact time of 119 ms for 8.25 m/s.

Horizontal velocity

The horizontal velocity is dependent upon the initial velocity (V_0), acceleration (a) and time (t).

$$V = V_0 + a \times t \qquad \text{(Eq. 1)}$$

The ratio between the duration of the braking phase (between touchdown and when the foot is directly under centre of gravity) and the propulsion phase (when the foot is directly under centre of gravity to takeoff) is from the viewpoint of economy (Mero and Komi, 1994) a very good indicator of a rational technique of maximal sprinting velocity. Coe et al. (n.d.) reported that the ratio between these was 40 % breaking phase and 60 % propulsion phase for his subjects.

Research on sprinters (Mero et al., 1992) has reported drops in velocity in the braking phase between 3.1 % and 4.8 % in a study by Coe et al. (n.d.) this number was 1.4 %.

Kinetics

Acceleration

The definition of acceleration is the change of velocity per time unit, but among sport scientists and coaches acceleration refers to sprint performance over short distances such as 5 and 10 metres.

During the stance phase there will occur a deceleration and acceleration. This negative or positive acceleration (a) is dependent on the ground reaction force (GRF) and the mass of the athlete (m). During running both vertical and horizontal accelerations exist.

$$a = F/m \qquad \text{(Eq. 2)}$$

Impulse

The impulse (I) is calculated by multiplying the force acting on a body with the acting time (t).

$$I = F \times t \qquad \text{(Eq. 3)}$$

The impulse during the stance phase can be divided into the impulse during the breaking phase and the impulse during propulsive phase. A good stance phase should have a large difference between breaking and propulsive impulses with the propulsive being the largest.

$$I_{propulsive} - I_{breaking} = \text{Large} \qquad \text{(Eq. 4)}$$

Force

The forces acting on the runner are the ground reaction force (GFR) and the air resistance. The maximal vertical ground force reaction (peak VGRF) varies in female sprinters between 1791 N and 2157 N, representing 3.2 to 3.7 times their body weight (Coh et al., n.d.). In a study with male athletes the peak VGRF was 2750 N to 2940 N (Skripko, 2003). A general tendency exists that both forces in the horizontal as well as in the vertical direction increase with velocity (Mero & Komi, 1987).

2.2. Jump assessments for predicting speed

There exist a lot of assessing methods for the functional power of the lower body.

The following eight jump assessment methods seem most widely used in the literature.

- *single hop for distance* (Bandy et al., 1994; Barber et al., 1990; Bolgla & Keskula, 1997; Clark et al., 2002; Paterno & Greenberger, 1996).
- *triple hop for distance* (Bandy et al., 1994; Bolgla & Keskula, 1997; Clark et al., 2002; Risberg et al., 1995).
- *6-m timed hop* (Barber et al., 1990; Bolgla & Keskula, 1997; Clark et al., 2002; Hopper et al., 2002).
- *crossover hop* (Bandy et al., 1994; Bolgla & Keskula, 1997; Clark et al., 2002; Hopper et al., 2002).
- *single leg vertical jump* (Bandy et al., 1994; Barber et al., 1990; Cordova & Armstrong, 1996; Hopper et al., 2002; Risberg et al., 1995).
- *vertical squat jump* (Arteaga et al., 2000; Cornwell et al., 2001; Cornwell et al., 2002; Knudson et al., 2001; Young, 1995; Young & Elliot, 2001).
- *vertical countermovement jump* (Arteaga et al., 2000; Cornwell et al., 2001; Cornwell et al., 2002; Hunter & Marshall, 2002; Knudson et al., 2001; Young, 1995).
- *drop jump* (Arteaga et al., 2000; Golomer & Fery, 2002; Hunter & Marshall, 2002; Young, 1995; Young & Elliot, 2001).

Other jump assessments that have been less used in research to measure lower body power include:

- *stair hop* (Hopper et al., 2002).
- *adapted crossover hop* (Clark et al., 2002).
- *side hop* (Itoh et al., 1998).

- *repeated vertical jumps* (Tkac et al., 1990).

It appears that a great variety of jumps are available for the assessment of leg power, therefore the question of interest to the strength and conditioning coach or clinician would be; which jump or jumps may be of better prognostic or diagnostic value. Obviously issues surrounding validity, reliability and sensitivity need to be addressed and should guide jump assessment selection. The use of unilateral assessment appears to have greater face validity as most forms of human locomotion involve unilateral propulsion. Unilateral assessment also has an advantage over bilateral assessment, as differences in limb symmetry can be identified and if injury has occurred, the non-injured limb can serve as the biological baseline to which the injured limb should return (Hopper et al., 2002).

Furthermore, locomotion is cyclic in nature and involves some preloading of the limbs during the eccentric contraction, prior to the propulsive or concentric phase. However, much of the jump assessment reported in the literature is acyclic in nature (Barber et al., 1990; Cornwell et al., 2001; Cornwell et al., 2002; Hopper et al., 2002; Itoh et al., 1998; Mero et al., 1983; Young, 1995; Young & Elliot, 2001). Finally, the propulsive phase is the result of a combination of horizontal, mediolateral and/or vertical ground reaction forces. However, there is a tendancy in the literature to measure only the vertical component of leg power.

If the sprinting gait of an athlete is divided into smaller segments, it can be observed that each stride is actually a horizontal one leg jump, only repeated many times and with both legs.

2.3. Statistical analysis

The methods for doing a statistical analysis are many. The understanding of what the numbers in the result actually stands for requires the understanding of the methods. When evaluating a new jump it is important to express the reliability and validity of the test.

2.3.1. Validity

"A variable of measure is valid if its values are close to the true values of the thing that the variable or measure represents" (Hopkins, 2000, para. 1). That is, if the variable measures what it's intended to do.

There are three main measures of validity; regression analysis, validity correlation and standard error of the estimate (can also be called typical error of the estimate, Hopkins, 2000, para. 11).

Correlation

The elementary idea of correlation is to "determine whether two variables are interdependent, or covary – that is, vary together" (Sokal & Rohlf, 1995, p.557). Since there are two variables that are being investigated, it is called bivariate correlation.

In correlation analysis, there is no difference made between dependent and independent variables and no attempt is made to predict one variable from the information of the other, as the intension is in regression analysis.

Normally a dependent variable is named x and the independent y, however since dependent/independent distinction does not exist in correlation, it has been suggested that the two variables should be called Y_1 and Y_2 (Sokal & Rohlf, 1995).

Type of data

To decide what kind of calculation method should be used, the researcher has to determine if the data collected is parametric or non-parametric. The data is parametric if it is; normally distributed, the populations from which the samples are drawn have equal variances and the data is measured, at the very least, on an interval scale. (Coolican, 1994)

Test method

If the data is determined to be parametric, which is the most common; the relationship between variables is usually calculated with Pearson's product moment correlation coefficient, r. If the data is non-parametric, the Spearman Rank Order correlation is the test to use. (Coolican, 1994)

The Pearson's correlation coefficient, r, is a value between -1 and 1. If the value is positive, the correlation is termed positive correlation, and subsequently the negative value refers to a negative correlation.

If the value Y_1 increases in a positive correlation, so do Y_2, if the correlation is negative Y_2 should decrease.

The evolution of computer technology over recent years has dramatically changed the availability for computer based statistical analysis. This has made correlation analyses very popular, with the right software it can be conducted within seconds. However to use the correlation calculation in the right context and to be able to interpret the result correctly, there is a big need for statistical knowledge.

Therefore four basic criteria has been set for correlatiom with parametric data, which has to be followed if the r value should be valid (Greenhalgh, 1997):

- The data should be normally distributed.
- The two datasets examined must be independent from one another.
- Only a single pair of measurements should be made on each subject.

- Every r value must come with p value.

Coefficient of determination

The r-squared value in percent ($r^2 \times 100$) is called the coefficient of determination and expresses the variance in one variable (Y_1) that can be attributed to its connection with the second variable (Y_2).

The correlation value r is very much affected by the variety of Y_1 and Y_2 (Smith, 1984). Large ranges in one or both variable can lead to a high correlation value, whereas a low variety can lead to decreased r values. For example, using both females and males in the same correlation calculation, can lead to high correlation values because of the high heterogeneity of the population.

Regression

Regression analysis is a mathematical identification of relationships between variables, if knowing the value for one or more variables (the predictor variables) a prediction of the value of another variable (the criterion variable) can be performed.

The mathematical theory underlining regression is that a linear function, $y = bx + a$, of ‘best-fits’ is made based on the method of least-squares, which attempts to minimize the sum of the squares of the differences (called residuals or prediction error) between points generated by the function and equivalent points in the data.

If there is just one predictor variable in the predictor formula, the regression type is called bivariate regression.

Multiple regressions

There is often a need for more then one predictor variable, so the bivariate regression is extended to situations where the criterion variable is associated to two or more predictor variables, called multiple regression, $y' = a + b_1x_1 + b_2x_2 \dots b_nx_n$.

The relationship between the predictor variables should be low, so that each predictor variable explains a unique variance, which is not common to other predictor variables (Winter et al, 2001).

There exist several methods for the adding of the predictor variables to the multiple regression formula. The most common method for multiple regression analysis reported in physiology and kin anthropometry research is the 'forward stepwise' method (Winter et al, 2001).
The forward stepwise method first calculates the best single predictor; the equation is then expended in a step-by-step procedure. The entry criteria for an independent variable into the regression equation is that a variable has to account for a significant (often $p<0.05$) amount of variance. Once a variable is entered into this equation it cannot be removed (with this method).

Standard error of the estimate

The aim with multiple regressions is, as has been mentioned before, to find the best solution to the prediction of y'. This is the solution with the lowest standard error of the estimate (SEE). SEE can be interpreted as the standard deviation of all the errors, or residuals, when predicting y' from x, and can be calculated from the standard deviation of y' (SDy') and the R^2 value, using the formula: $SEE = SDy' (1-R^2)0.5$.

The SEE value is a commonly reported figure in studies and gives the necessary means of which the confidence intervals for the precision of the prediction can be calculated. Sixty-eight percent of the error in the prediction will be between ± 1 × SEE, 95 % will be between ± 1.96 × SEE and 99 % ± 2.58 × SEE. (Vincent, 1999).

Coefficients

There are several variables generated by the statistical software (for example SPSS) together with the regression equation formula. One of them is the coefficient of multiple regression (R), which is an index of the accuracy of the equation and can be seen as a simple Pearson correlation between the predicted y-scores and the true/real y-scores for each subject. This variable (R) can also be squared to form the coefficient of determination (R^2).
R^2 is used to investigate the proportion of y’ variance that is predictable on the basis of scores on the predictor variables (Kinnear & Gray, 1997).

2.3.2. Reliability

Reliability relates to the repeatability or reproducibility of a measure or variable. There are three important measures of reliability, within-subject variation, change in the mean, and retest correlation (Hopkins, 2000) that should be used to establish the reliability of testing procedures. The within-subject variation is the most important type of reliability measure for researchers, because it affects the precision of the estimates of change in the variable of an experimental study. The smaller the within-subject variation is the easier it will be to measure a change in performance or health. (Hopkins, 2000). The coefficient of variation (CV) is a measure of typical percent error. This error is equivalent to the standard deviation (SD) of an individual’s repeated measurements, as a percent of the individual’s mean test score. (Hopkins, 2001).

Another measure of reliability is simply the change in the mean value between two trials of a test. The change consists of two components: a random change and a systematic change. Random change in the mean is due to so-called sampling error and is smaller with larger sample sizes. Systematic change in the mean is a non-random change in the value between two trials that applies to all study participants and could be caused by learning or training effect but also from fatigue or loss of motivation. (Hopkins, 2000).

The test-retest correlation represents how closely the values of one trial track the values of another as the attention moves from individual to individual. If each participant has an identical value in both trials, the correlation coefficient has a value of one, as they start to differ from each other the value approaches against zero. The correlation also represents how well the rank order of participants in one trial replicated in the second trial. The main problem with retest correlation is that the value of correlation is sensitive to the heterogeneity of values between participants. (Hopkins, 2000)

The intraclass correlation (ICC) is the recommended statistic for quantifying the test-retest reliability of a physical measurement procedure in sports medicine (Denegar & Ball, 1993). The most common methods of ICC are based on the calculation of the F-value from repeated measures ANOVA (Atkinson, 1998). There are at least 6 ways of calculating an ICC and all methods are giving different results (Ottenbacher & Tomcheck, 1994; Muller, 1994). Vincent (1994) provided ranging system for ICC were 0.7 to 0.8 is ‘questionable’ and >0.9 is ‘high’ and close to one indicates ‘excellent’. An ICC should only be employed when a fixed population of individuals can be well defined (Quan & Shih, 1996).

2.4. Conclusion

Given all the information about sprint running it would seem that a valid test of muscular function and leg power for sprint running should involve unilateral, horizontal-vertical and pre-loading components for assessment of the leg musculature. There are a lot of different jumps in use today but still the most common jump is a bilateral vertical jump.

A new test should be evaluated for the validity and reliability. To evaluate the validity it is recommended to use Pearson's correlation and regression analysis. The reliability should be carried out intra- and interday and the important measurements are coefficient of variation, percentage change of mean and intraclass correlation

3. Methodology

3.1. Development of a test protocol

At the start of this study guidelines already existed with many details regarding how the jump test should be performed. However, there were no exact details specified and there were no existing test protocols. Therefore the first phase of the project was to develop a new testing protocol to use. The new jump protocol should be as specific to sprint running as possible for better predicting ability. However, it should be standardised to ensure good reliability.

3.2. Subjects

Twenty male volunteers competing in different sports at regional level in New Zealand were accepted as subjects. Most of the subjects were students at Auckland University of Technology (AUT). The subjects were competing in sports that involved a lot of running or running and jumping, e.g. rugby and basketball. Three of the participants came from a sport with less running or jumping; volleyball, kayak and weightlifting.

The anthropometric values for the subjects were (mean ± SD); age 22 ± 2.5 years, height 180 ± 6.6 cm, weight 80.4 ± 9.4 kg.

The subjects were recruited to this study by responses to advertisements placed on notice boards at Auckland University of Technology (AUT) or by personal recruitment by the researchers.

The study was approved by the Auckland University of Technology Ethics Committee, through the cooperative paper approval (reference number 05/61). After the subjects had read the participant information sheet and had all questions answered, all subjects gave written consent.

3.3. Test protocol

All tests were performed in the gym of AUT Sport and Fitness Centre at the Akoranga campus, of Auckland University of Technology. The tests were performed during a 4 week period in March 2006. No special consideration was taken of what time in the day the tests were conducted, however all tests were undertaken during normal work hours.

All subjects completed a sprint test and a jump test in the same test session. The subjects were given a 5 minutes rest period between the two tests. The order of the jump and sprint assessment was randomized. The duration of the test session was approximately one hour. The subjects were instructed not to conduct any heavy leg training in the two days prior to the test day.

3.3.1. Warm up

The subjects were instructed to perform a self selected jogging for 5-10 minutes. After the jogging the subjects were given the opportunity to do self selected warm up exercises. Twelve warm up jumps were performed, two for each different jump assessment, before the jumping session. Two sub maximal sprints were performed before the sprint session.

3.3.2. Familiarization

The need for familiarization for the sprints was minor; however, the two sub maximal sprints were performed in the same procedure as the actual sprint test.

The need for familiarization for the jumps being tested was much higher; because the many of the jumps were completely new for most of the subjects. The subjects were encouraged to do several warm up jumps, to find the movement pattern required. There was no objective measuring of when the subject was familiarized, however when the subjects performed the jumps in a satisfactory way and felt comfortable with the jumps, they were considered familiarized.

3.3.3. Jump assessments

The jumps that were assessed were; single and double leg vertical drop jumps and single and double leg horizontal drop jumps. The single leg jumps were performed with both the right and the left leg, which made a total of six jumps tested.

The order of the jumps was randomized to negate order and fatigue effects. For the double leg jumps, the minimum jumps conducted was three and for the one leg jump the minimum was four jumps. The maximum for both one and two leg jumps was six jumps. Generally there was a performance plateau within these trials.

Description of the setup

Installation of the force plate

The force plate (type 9287 B; Kistler, Switzerland) was first attached to the force plate control unit (type 5223A, Kistler, Switzerland). The control unit was then connected to a BNC-2110 block (National Instruments) through eight cables, one for each channel (X1+2, X3+4, Y1+2, Y3+4, Z1, Z2, Z3 and Z4). The BNC-2110 block was then linked to a Data Acquisition card which was connected to the laptop.

The software installed on the laptop, which controlled the collection of data from the force plate, was Labview 6 (National Instruments). The sampling rate for the software was set to 500 Hz (Canavan & Vescovi, 2004).

The force plate was activated at least 30 minutes before the first test, to minimise drifting.

Horizontal jump length measuring setup

To measure the jump off for the horizontal jumps, a red tape was placed on the force plate (40 cm from the step up box), with 4 tapes behind the first one with a distance of 2 centimetres in between.

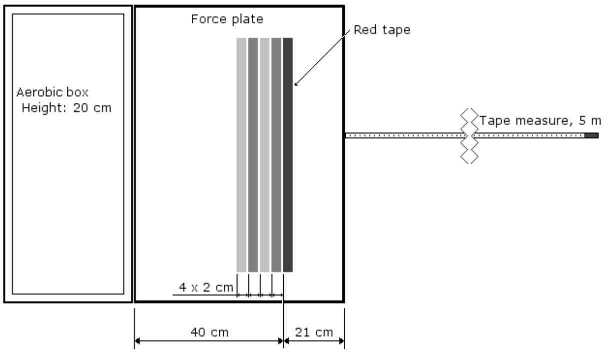

Figure 2: The horizontal measure setup

To measure the length of the jump, a tape measure was used and on the floor there was tape set every 10 centimetres. The jumps were performed from a 20 cm high step up box placed precisely behind the force plate.

In order not to interfere with the landing on the force plate, the beginning of the tape measure was placed directly in front of the force plate. All jumps were recorded with a video camera located approximately 10 meters in front of the subject.

Measure of the jump

The horizontal distance was measured from the toe that was nearest to the red overstep line to the heal that landed at the shortest distance. The subjects were instructed to land without falling forwards or backwards. If the subject fell forward the jump was correct, however if the fall was backwards the jump was false and repeated. If the subject stepped over the red line the jump was false and repeated. The repeated jump was done directly after the false jump. If there were two false jumps in a row a longer rest was taken after the second. The one minute rest period between the jump trials were measured with a stopwatch which was running through the whole jump test session. One jump was conducted every minute. The distance of the horizontal jumps were measured with a tape measure and written down on the data collection sheet. The landing from the horizontal jumps was made with one foot on either side of the tape measure, to make the measuring more exact.

Descriptions of the jumps

The descriptions given to the subjects on each jump are stated below:

Single leg horizontal drop jump

The subjects were instructed to have their hands affixed to the hip and to stand on the step up box. The subjects were then instructed to drop onto a force plate on one leg and jump maximally for horizontal distance, but with minimized ground contact time. This single leg jump was performed with both the left and the right leg.

Figure 3: Descriptions of the single leg horizontal drop jump

Double leg vertical drop jump

The subjects were instructed to have their hands affixed to the hip and to stand on the step up box. The subjects were then instructed to drop onto a force plate and jump maximally for height, but with minimised ground contact time.

Single leg vertical drop jump

The subjects were instructed to have their hands affixed to the hip and to stand on the step up box. The subjects were then instructed to drop onto a force plate on one leg and jump maximally for height, but with minimised ground contact time. This single leg jump was performed with both the left and the right leg.

Double leg horizontal drop jump

The subjects were instructed to have their hands affixed to the hip and to stand on the step up box. The subject was then instructed to drop onto a force plate and jump maximally for distance, but with minimized ground contact time.

3.3.4. Sprint assessment

The assessment was over 25 metres and a minimum of three trials were performed by the subjects and a maximum of six trials. The test stopped when the performance had reached a plateau. The rest between the sprints was between 3-5 minutes.

Figure 4: Setup of the timing lights

Description of the setup

For the assessment of sprint speed a full court gymnasium was used at the AUT Fitness Centre. The distances were measured with a tape measure and marked with tape. The distances marked were; 0.5 metre before start line, the start line and 5, 10 and 25 metres away from the start line, finally a distance of 27 metres from the start line. The four pairs of timing lights were placed approximately 1.2 metres apart from each other and on either side of the tape marking the start line, 5, 10 and 25 metres. The height of the timing lights was 85 centimetres. After the timing lights were placed in the correct position a control measure was performed by measuring both the right and the left timing lights. At the mark 0.5 metre before the start line a larger piece of tape was placed to indicate the starting position for the subject. The mark at 27 metres was used for placing two cones.

The timing lights were connected in sequence and the first one was connected to a hand held computer that displayed split times. The timing lights started beeping when they did not receive a reflection from their partner. This indicated they needed to be adjusted. Before assessing the sprints, a lot of hard stomps were made around the timing lights to see that they did not lose contact with the partner on the other side.

Measure of the sprint

The subjects were assessed over 25 metres, with splits set at 5 and 10m. The results from the trials were recorded on the test protocol. If the start was performed incorrectly the trial was repeated and the result was eliminated.

Descriptions of the sprint

Each sprint began from a two foot parallel position 50 centimetres behind the first timing light. The subjects were instructed to make the first running step forward and to run all the way to the two cones placed 2 meters behind the last timing light.

3.3.5. Anthropometric assessments

During the 5 minutes break between the jump and the sprint assessments, the height and weight of the subject were measured using a Seca 770 scale and a stadiometer. The height was measured twice, to ensure that the result was correct.

3.4. Data Analysis

Due to lack of time, the only jump that was analysed was the single leg horizontal drop jump.

3.4.1. Jump data

Every file recorded during the tests was re-opened in the analysis module of the software, Labview 6. The idea was to identify the ground contact phase using the data from the force plate. A low pass filter set to 6 Hz was utilised (Winter, 1980; Antonsson, 1985; Kerwin & Chapman, 1988). The contact phase was set to begin when the force from the force plate was greater then 10 N and to end when the force was less then 10 N (McLean et al, 2005).

Fifteen jump trials (of totally 180 trials) from seven different subjects were deleted, due drifting of the adjustment to zero. From each trial a summary file was saved from the software containing all the data that was of interest.

The summary files from Labview 6 were opened in Microsoft Excel and all the data was entered into another Excel spreadsheet. The data was ordered subject by subject and within each subject, jump type by jump type.

For each subject the two longest jumps were identified and entered in a new table. Mean values of all values (distance, contact time, mean force and max force) were calculated. Furthermore, the two trials with the best Reactivity coefficient (RC), RC = Jump distance / contact time, were identified and mean values were calculated.

These mean values were once again entered in a new Excel spread sheet, ordered jumps with left leg for all the subjects and then the jumps with the right leg. The best sprint times (5, 10, 25, 5-10 and 10-25m) were added to this excel spreadsheet.

3.4.2. Sprint data

The results from all trials for all subjects were entered into an excel spreadsheet. The two best times for every subject over each distance (5, 10 and 25 m) and also for the 5-10m and 10-25m times, were identified and put into a separate sheet. A mean value of the two best times for each distance was calculated for all subjects.

3.5. Statistical analysis

The force plate produced many variables to choose from and the selection of a few of them was necessary.

The variables that were chosen to be analysed were; jump distance, ground contact time (CT), horizontal impulse (impulse H), vertical impulse (impulse V), horizontal mean force (mean HGRF), vertical mean force (mean VGRF), horizontal peak force (peak HGRF), vertical peak force (peak VGRF), and reactivity coefficient (RC).

The jump was performed on both the right and the left leg but a t-test showed that there were no significant ($p<0.559$) difference between the legs. Therefore the mean of both right and the left foot were pooled.

Before any statistical analyses were conducted, a search for outliers in the data was made. This was done in order to find cases of extremely large residual values, which might affect the result in the statistical analyse (Vincent, 1999).

3.5.1. Definitions of measurements

Mean/peak H/V-GRF: In this study the mean and maximal horizontal and vertical ground reaction force have been measured, in negative X (horizontal) direction and positive Z (vertical) direction. Unit: Newton (N).

Impulse V, H: The product obtained by multiplying the average value of a force by the time during which it acts. $I = F \times t$. Unit: Newton seconds (Ns).

CT: Contact time, the time in which the subject is in contact with the force plate (ground). Unit: seconds (s).

RC: Reactivity coefficient: In this study the distance which a subject jumped was divided by the contact time. RC = Jump dis. / CT. Unit: centimetres / seconds (cm/s).

BM: The body mass of the subject. Unit: kilogram (kg).

Height: The height of a subject from foot to head. Unit: centimetres (cm).

3.5.2. Validity

The final outcome from the data analyses was imported into the statistical software SPSS 14.0 for windows. Two different types of statistical analyses were conducted; correlation and linear regression.

Correlation

Pearson product moment correlations were used to determine the strength of the relationship between the sprint measures and the jump measures.

Linear regression

The aim of this analysis was to identify those factors that were important in predicting sprint performance (5, 10, 25, 5-10 and 10-25m). For this purpose, forward stepwise multiple regression analysis was used using a number of anthropometric and kinetic measures (jump distance, jump distance/height, RC, CT, Impulse V,H, mean/peak VHRF, mean/peak HGRF, BM, height). The forward stepwise regression began with no variables in the equation and thereafter entered the most "significant" predictor at the first step and continued to add or delete variables until none "significantly" improved the fit. Minimum tolerance for entry into the model and alpha-to-enter/remove were set at 0.05 and 0.10 respectively. From this analysis the best multiple predictor model for sprint 5m, sprint 10m, sprint 25m, sprint 5-10m and sprint 10-25m were derived. Regression diagnostics were used to examine normality, variance, collinearity, outlier effects, leverage and influence. A 0.05 level of significance was adopted for all statistical models.

3.5.3. Reliability

The raw data was sorted so the jumps with the two best jump distances were selected. These jumps were used for calculating the mean, standard deviation (SD) and the coefficient of variation (CV). The mean values were calculated for each day and the SD was calculated by taking the average of the individual SD. The CV was calculated by averaging of the CV from the right and the left leg.

Two subjects were taken away from the first test because of incorrect landing technique which was noticed when observing at the video footage. On the second day two subjects did not show up and therefore there were 18 subjects who completed the first test (day 1) and 18 subjects who completed the second test (day 2).

The variables used were the mean, SD and CV. The mean value was calculated for each day and the mean for both legs were used. The SD was calculated by taking the average of the individual SD. The CV was calculated by the average of the CV from the right and the left leg. The same procedure was used for both days.

For the interday reliability the mean results from the best and second best jumps were calculated. A new mean value from the first and second day’s mean values was calculated for all the 16 subjects, which completed both the first and second test correctly. The used CV was calculated by taking the average of all the individual CVs from each subject. The percentage changes of the mean was calculated by taking the mean from the second test minus the mean from the first and dividing that by the first test’s mean value. The ICC was calculated in SPSS 14.0 and ICC used was a two-tailed mixed consistency

3.5.4. Biomechanical calculations

The data used in the statistical analysis were also used for specific biomechanical calculations, such as calculating the total ground reaction force (TGRF) and the angle between the TGRF and the HGRF. All the values corresponding to the different subjects were also sorted in the best sprint times for 10 and 10-25 meters, making it possible to divide the subjects into two groups. T-tests were then performed between the groups on several variables.

4. Results

The result section is divided into two parts; validity followed by the reliability.

4.1. Validity

There were two methods used to identify the two best jumps from which a mean value was calculated: Best jump distance and best reactivity coefficient (RC). To analyse the data, correlation and linear regression were calculated.

4.1.1. Sprint times

Depicted in Table 1: Sprint times, mean and the SD values. The mean value for the first 5 metres (1.13 s) is higher than the mean value for the split time 5-10 metres, the SD is also higher.

Table 1: Sprint times, mean and the SD values.

Sprint	Mean (s)	SD (s)
5 m	1.13	0.05
10 m	1.87	0.07
25 m	3.78	0.15
5-10 m	0.74	0.03
10-25 m	1.90	0.08

4.1.2. Best jump distance

The two longest jump trials where identified (together with the corresponding jump kinematics); from those two trials a mean value was calculated.

Correlation

Table 2: Correlations between sprint times and jump kinematics using best jump-method.

	Sprint 5m	Sprint 10m	Sprint 25m	Sprint 5-10m	Sprint 10-25m
BM (kg)	0.113	0.205	0.239	0.343(*)	0.235
Height (cm)	-0.052	-0.030	0.024	0.007	0.025
Jump dis. (cm)	-0.547(**)	-0.610(**)	-0.509(**)	-0.537(**)	-0.398(*)
Jump dis. / height	-0.572(**)	-0.648(**)	-0.563(**)	-0.585(**)	-0.443(**)
RC (cm/s)	-0.137	-0.156	-0.109	-0.071	-0.070
CT (s)	-0.105	-0.101	-0.121	-0.166	-0.122
Impulse H (Ns)	0.001	-0.061	-0.170	-0.143	-0.254
Impulse V (Ns)	-0.355(*)	-0.332(*)	-0.315(*)	-0.299	-0.267
Mean HGRF (N)	-0.093	-0.171	-0.280	-0.283	-0.353(*)
Mean HGRF / CT (N/s)	-0.168	-0.243	-0.334(*)	-0.363(*)	-0.386(*)
Mean VGRF (N)	-0.425(**)	-0.372(*)	-0.317(*)	-0.217	-0.236
Mean VGRF / CT (N/s)	-0.140	-0.070	-0.035	0.091	0.009
Peak HGRF (N)	-0.158	-0.201	-0.289	-0.249	-.350(*)
Peak HGRF / CT (N/s)	-0.217	-0.261	-0.334(*)	-0.329(*)	-0.374(*)
Peak VGRF (N)	-0.369(*)	-0.326(*)	-0.237	-0.176	-0.138
Peak VGRF / CT (N/s)	-0.102	-0.034	0.010	0.110	0.058

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations: BM = Body mass, RC = Reactivity Coefficient, CT = Contact Time, HGRF = Horizontal Ground Reaction Force, VGRF = Vertical Ground Reaction Force, Height = height of the subject.

It can be observed from table 5 that all the sprint times measured (5, 10, 25, 5-10 and 10-25m) correlate significantly to the jump distance (r = -0.547, -0.610, -0.509, -0.537 and -0.398, $p < 0.01$ and $p < 0.05$), where the division with the height increases the correlation (r = -0.572, -0.648, -0.563, -0.585 and -0.443, $p < 0.01$). The highest correlation can be found between the 10 meters sprint and jumping distance divided by height (r = -0.648). No kinetic variable (impulse, VGRF and HGRF) correlate highly to any of the sprint times assessed.

Linear Regression

For every sprint time a stepwise linear regression formula was calculated together with the corresponding R^2 value, the standard error of the estimate in seconds (SEE) and the standard error of the estimate in percentage of the mean (%SEE).

$$\underline{\text{Sprint 5m (s)}} = (-0{,}374 \times \text{Jump dis./height}) + (-0{,}027 \times \text{Peak HGRF/CT}) + (-0{,}078 \times \text{Mean VGRF}) + 1{,}550 \quad \text{(Eq. 5)}$$

$R^2 = 0.55$ SEE = 0.033 s %SEE = 2.88 %

$$\underline{\text{Sprint 10m (s)}} = (-0{,}793 \times \text{Jump dis./height}) + (-0.057 \times \text{Peak HGRF/CT}) + 2{,}519 \quad \text{(Eq. 6)}$$

$R^2 = 0.65$ SEE = 0.045 s %SEE = 2.42 %

$$\underline{\text{Sprint 25m (s)}} = (-1.498 \times \text{Jump dis./height}) + (-0.130 \times \text{Peak HGRF/CT}) + 4.951 \quad \text{(Eq. 7)}$$

$R^2 = 0.60$ SEE = 0.10 s %SEE= 2.69 %

$$\underline{\text{Sprint 5-10m (s)}} = (-0.320 \times \text{Jump dis./height}) + (-0.052 \times \text{Mean HGRF/CT}) + 0.983 \quad \text{(Eq. 8)}$$

$R^2 = 0.67$ SEE = 0.019 s %SEE= 2.54 %

$$\underline{\text{Sprint 10-25m (s)}} = (-0{,}699 \times \text{Jump dis./Height}) + (-0{,}136 \times \text{Mean HGRF/CT}) + 2{,}411 \quad \text{(Eq. 9)}$$

$R^2 = 0.49$ SEE = 0.063 s %SEE= 3.33 %

All the regression formulae include jump distance/height as the first prediction variable. For the sprint times with flying start (5-10 and 10-25 m) the second predictor variable is the mean HGRF/CT, and for the sprint times 5, 10 and 25 m is the second predictor variable peak HGRF/CT.

4.1.3. Best Reactivity Coefficient

The two jump trials with the highest RC where identified (together with the corresponding jump kinematics); from those two trials a mean value was calculated.

Correlation

Table 3: Correlations between sprint times and jump kinematics using best RC-method.

	Sprint 5m	Sprint 10m	Sprint 25m	Sprint 5-10m	Sprint 10-25m
BM (kg)	0.113	0.205	0.239	.343(*)	0.235
Height (cm)	-0.052	-0.030	0.024	0.007	0.025
Jump dis. (cm)	-.538(**)	-.608(**)	-.508(**)	-.540(**)	-.398(*)
Jump dis. / height	-.561(**)	-.644(**)	-.562(**)	-.588(**)	-.444(**)
RC (cm/s)	-0.139	-0.151	-0.117	-0.066	-0.085
CT (s)	-0.152	-0.173	-0.168	-0.234	-0.150
Impulse H (Ns)	0.007	-0.033	-0.141	-0.101	-0.222
Impulse V (Ns)	-.418(**)	-.414(**)	-.380(*)	-.369(*)	-.318(*)
Mean HGRF (N)	-0.096	-0.170	-0.267	-0.273	-.334(*)
Mean HGRF / CT (N/s)	-0.185	-0.271	-.351(*)	-.388(*)	-.399(*)
Mean VGRF (N)	-.419(**)	-.374(*)	-.332(*)	-0.231	-0.262
Mean VGRF / CT (N/s)	-0.157	-0.102	-0.090	0.036	-0.063
Peak HGRF (N)	-0.161	-0.207	-0.291	-0.255	-.348(*)
Peak HGRF / CT (N/s)	-0.235	-0.295	-.362(*)	-.366(*)	-.399(*)
Peak VGRF (N)	-.362(*)	-.313(*)	-0.243	-0.170	-0.156
Peak VGRF / CT (N/s)	-0.118	-0.068	-0.043	0.053	-0.010

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Abbreviations: BM = Body mass, RC = Reactivity Coefficient, CT = Contact Time, HGRF = Horizontal Ground Reaction Force, VGRF = Vertical Ground Reaction Force, Height = height of the subject.

It can be observed from table 3 that all the sprint times measured (5, 10, 25, 5-10 and 10-25m) correlate (in a similar way as in table 2) significantly to the jump distance ($r = -0.538, -0.608, -0.508, -0.540$ and -0.398, $p < 0.01$ and $p < 0.05$). Analogue with table 2, the division with the height increases the correlation ($-0.561, -0.644, -0.562, -0.588$ and -0.444, $p < 0.01$). The highest correlation can be found between the 10 meters sprint and jumping distance divided by height ($r = -0.644$).

Linear Regression

For every sprint time a stepwise linear regression formula was calculated together with the corresponding R^2 value, the standard error of the estimate in seconds (SEE, s) and the standard error of the estimate in percentage of the mean (SEE, %).

Sprint 5m (s) = (-0.367 × Jump dis./Height) + (-0.020 × Impulse V) + (-0.062 × Peak HGRF) + 1.541 (Eq. 10)

$R^2 = 0.55$ SEE = 0.033 s %SEE= 2.88 %

Sprint 10m (s) = (-0.717 × Jump dis./Height) + (-0.045 × Peak HGRF/CT) + (-0.019 × Impulse V) + 2.564 (Eq. 11)

$R^2 = 0.70$ SEE = 0.043 s %SEE= 2.28 %

Sprint 25m (s) = (-1.415 × Jump dis./height) + (-0.130 × Peak HGRF/CT) + 4.845 (Eq. 12)

$R^2 = 0.60$ SEE = 0.10 s %SEE= 2.67 %

Sprint 5-10m (s) = (-0.367 × Jump dis./height) + (-0.044 × Mean HGRF/CT) + (0.0001 × RC) + 0.981 (Eq. 13)

$R^2 = 0.72$ SEE = 0.017 s %SEE= 2.37 %

Sprint 10-25m (s) = (-0.656 × Jump dis./height) + (-0.073 × Peak HGRF/CT) + 2.369 (Eq. 14)

$R^2 = 0.49$ SEE (s) = 0.064 s %SEE= 3.35 %

All the regression formulas include jump distance/height as the first prediction variable. The second and third predictor variable changes between the formulas, however HGRF appears frequently, often divided with CT.

4.2. Reliability

4.2.1. Amount of jumps

The amount of jumps needed to find a plateau is presented in Table 4. There were no significant ($p<0.181$) differences between the legs. No subject performed less then four jumps or more than six jumps , except for one case where seven jumps were needed to find a plateau. The mean and SD for the amount of jumps needed was 4.49 ± 0.74.

Table 4: Amount of jumps performed

Leg	Mean	SD
Right	4.39	0.64
Left	4.58	0.83
Mean	4.49	0.74

4.2.2. Intraday reliability

The mean and standard deviation for the nine variables measured from the jumps are presented in Table 5. The between-trial variability of all kinematic and kinetic measures was less than 7%. The most consistent measure over both trials was the horizontal distance jumped (1.2 to 1.4%) and the most variable were the CT the first day (6.5%) and peak HGRF the second day (-4.3%). In all cases there were less variation associated with the second day.

Table 5: Intraday reliability. Mean, standard deviation (SD), coefficient of variation (CV) for the jump variables in the first and the second test.

Variable	**Day 1 N = 18**			**Day 2 N = 18**		
	Mean	SD	CV	Mean	SD	CV
Distance (cm)	171	15	1.4	172	15	1.2
CT (s)	0.41	0.06	6.5	0.39	0.04	4.1
Impulse H (Ns)	-139	26	5.6	-140	22	3.8
Impulse V (Ns)	463	99	4.5	437	72	3.6
Mean HGRF (N)	-363	58	6.0	-386	58	4.1
Mean VGRF (N)	1135	153	3.8	1130	116	3.3
Peak HGRF (N)	-630	102	5.6	-674	97	4.3
Peak VGRF (N)	1880	247	5.6	1928	219	4.1
RC (cm/s)	426	73	6.1	453	68	4.0

Abbreviations: RC = Reactivity Coefficient, CT = Contact Time, HGRF = Horizontal Ground Reaction Force, VGRF = Vertical Ground Reaction Force.

4.2.3. Interday reliability

In terms of test-retest variability the percentage change in the means and CVs were all under 10% (see table 6). The smallest changes in the mean (0.43 %), least variation (< 2.26 %) and next highest ICCs (≥0.95) were found for distance. The highest ICC (≥0.96) was found for the horizontal impulse.

Table 6: Interday reliability: Percentage change of the mean, coefficient of variation (CV) and intraclass correlation coefficients (ICC) for the jump variables.

Variable	**% Change**	**CV(%)**	**ICC**
Distance (cm)	0.43	2.26	0.95
CT (s)	-2.47	5.04	0.90
Impulse H (Ns)	2.53	4.74	0.96
Impulse V (Ns)	1.16	8.28	0.84
Mean HGRF (N)	6.50	5.66	0.95
Mean VGRF (N)	2.81	5.74	0.74
Peak HGRF (N)	6.81	5.86	0.94
Peak VGRF (N)	4.60	5.71	0.84
RC (cm/s)	7.25	7.78	0.84

Abbreviations: RC = Reactivity Coefficient, CT = Contact Time, HGRF = Horizontal Ground Reaction Force, VGRF = Vertical Ground Reaction Force.

4.3. Biomechanics

In table 7 the grand mean for the variables are presented together with the mean value for the 10 best sprinters (10 m and 10-25 m), mean value for the 10 worse sprinters and a t-test value when comparing the top 10 sprinters with the bottom 10 sprinters. As can been seen there are more significances associated with 10 meters. The best significant difference between bottom and top was found for the horizontal impulse in 10 meters and the second best was the jump distance divided by height also found in 10 meters. The jump distance is the only variable that have a significant different in both 10 and 10-25 meters.

Table 7: Calculations of biomechanical variables

Variables	**Mean**	**10 meters**			**10-25 meters**		
		Top 10	Bottom 10	T-test	Top 10	Bottom 10	T-test
BW (N)	789	805	772	0.34	760	817	0.14
Height (cm)	180.2	180.0	180.5	0.86	179.5	181	0.67
Distance (cm)	172	180	164	0.03(*)	178	166	0.03(*)
CT (s)	0.395	0.404	0.385	0.30	0.404	0.385	0.64
Impulse H (Ns)	-138	-151	-126	0.01(**)	-134	-143	0.41
Impulse V (Ns)	442.4	477.9	402.5	0.03(*)	456.2	426.9	0.66
RC (cm/s)	453.8	460.7	446.1	0.82	465.9	439.5	0.42
Peak HGRF (N)	-648.9	-670.7	-627.0	0.61	-600.8	-696.9	0.02(*)
Peak VGRF (N)	1890	1968	1801	0.04(*)	1873	1908	0.75
Peak TGRF (N)	1993	2069	1908	0.07	1960	2032	0.99
Peak TGRF Angle (°)	70.9	71.0	70.8	0.70	71.9	69.9	0.25
Peak TGRF/BW	2.59	2.59	2.58	0.72	2.61	2.56	0.50
Jump distance/Height	0.950	0.992	0.909	0.02(*)	0.987	0.914	0.10
VGRF/BW	2.45	2.46	2.44	0.86	2.50	2.40	0.39

(**) Significant at the 0.01 level (2-tailed), (*) Significant at the 0.05 level (2-tailed).

Abbreviations: TGRF = Total Ground Reaction Force

5. Discussion

The major purpose with this study has been to develop a new jump test and determine the validity and the reliability of it (SHDJ). The three other jump tests (double leg vertical drop jump, single leg vertical drop jump and double leg horizontal drop jump) were performed for comparison to the SHDJ. However, because of lack of time the analysis of these jumps were not possible.

Validity

There is a preoccupation in the literature with investigating the relationship between vertical bilateral jumps and athletic performance such as sprinting. In terms of face validity, such an approach may be somewhat flawed as sprinting involves unilateral ground contacts with the muscles being preloaded during the eccentric phase and the production of horizontal and not just vertical forces. Therefore, the current study was conducted to investigate the relationship between sprint performance (5, 10, 25, 5-10 and 10-25 meters) and a single leg horizontal drop jump, involving both a vertical and horizontal component.

Significant correlations were found between all sprint times (5, 10, 25, 5-10 and 10-25m) and jump distance/height ($r_{JUMP} = -0.44$ to -0.65, $r_{RC} = -0.44$ to -0.64, $p < 0.01$), with the highest correlations found for the 10m sprint time. From the correlation matrix it was observed that the most highly correlated variable with the sprint times was jump distance/height. Following this the best correlation variable with the early sprint times (5 and 10m) was VGRF and for the others sprint times (25, 5-10 and 10-25m) the HGRF. As the highest correlations were found for the 10m sprint time, this could indicate that the jump assessment performed is slightly more specific to the characteristics (kinetics, ground contact time etc) associated with that distance.

There is a paucity of literature that has examined the relationship between measures of horizontal jump performance and sprint performance. Maulder & Cronin (2005) in a study using team sport athletes, reported strong relationship between 20 meter sprint times and horizontal jump squat, horizontal countermovement jump and horizontal repetitive (cyclic) jump (r = -0.73, -0.74 and -0.86 respectively). Nesser et al. (1996) in a study also using team sport athletes, reported a strong correlation between sprint speed over 40 meter and a 5-step horizontal jump (r = 0.81).However, Maulder et al. (2006) in a study using track sprinters, reported non-significant weak correlation between single leg hop for distance, single leg triple hop for distance and sprint speed over 10 meters (r = -0.30 to 0.33). It may be that performance in horizontal jumps may be less able to predict sprint speed over 10 metre for track athletes using a block start.

The highest correlation coefficient in this study was -0.65 (for jump distance/height and sprint speed over 10m), which is slightly lower then the values reported by Maulder & Cronin (2005) and Nesser et al. (1996). One can speculate on the reason for this difference, which could be the use of a drop jump instead of horizontal squat/countermovement jumps, i.e. a difference in methods.

A greater number of studies have quantified the relationship between vertical jumps and sprint performance. The results from these studies can be divided into three groups depending on correlation coefficients reported.

Maulder & Cronin (2005), Wisloff et al. (2004) and Liebermann & Katz (2003) reported significant correlations between vertical jumps and sprint speed (r = -0.52 to 0.86). However, the correlation result from Liebermann & Katz (2003) can be questioned because of the use of both males (11) and females (6) which is likely to increase the heterogeneity of the group with respect to the sprinting and jumping values, ultimately inflating the magnitude of the correlation (Smith, 1984).

Nesser et al (1996) reported significant correlations (r = -0.464) between countermovement jumps and 40 m sprint. Furthermore, Kukolj et al (1999) reported significant correlations (r = -0.48) between countermovement jumps and sprints measured between 15-30 m.

Chamari et al (2004) reported non significant correlations between the height of vertical jumps and 20 and 30 m sprints. In addition Maulder et al (2006) reported non significant correlations between the height of vertical jump and 10 m sprints, assessed on sprinters.

The reasons for the inconsistency in the correlations between studies could be attributed to many factors. For example, Maulder & Cronin (2005) studied one leg vertical jumps in comparison to the traditional two legged vertical jumps. There are also differences in the method used to assess the height of the vertical jump; Wisloff et al (2004), Chamari et al (2004) and Maulder et al (2006) used a force plate. Maulder & Cronin (2005) and Kukolj et al (1999) used a contact matt and Liebermann & Katz (2003) used a hand reach test.

Studies that report both force/power and height measures (correlated to sprint performance) have a higher correlation value for the force/power variables (Liebermann & Katz, 2003; Chamari et al, 2004; Maulder et al, 2006). It may be that the measuring of height is less predictive of sprint speed then measuring vertical force/power.

The subjects used in the studies vary, from sprinters (Maulder et al, 2006) and international soccer players (Wisloff et al, 2004) to recreationally active people (Maulder & Cronin, 2005; Liebermann & Katz, 2003; Nesser et al, 1996; Kukolj et al, 1999; Chamari et al, 2004).

Stepwise multiple linear regression was used to find predictor models of sprint performance using the kinematic and kinetic variables measured during the horizontal jump. The jump distance/height and the HGRF were two best predictor variables, with R^2 values of 0.50 to

0.72. That is, that these two variables explain between 50-72 % of the variance associate with sprint performance over all the distances assessed. However, other variables, not assessed in this study, such as anthropometry (e.g. leg length) and flexibility (e.g. hip flexor length and hamstrings length) may play an important role and add to the predictive ability of the models. The two methods used in this study to identify the two best jump trials, best jump distance and best RC, gave very similar results, suggesting that these two methods, for this purpose, are equally effective in predicting sprint performance. One little difference can however be seen in the regression analysis, where the best RC method gave slightly higher R^2 values.

Very few studies have used regression analysis as an approach for predicting sprint performance. However, Maulder et al (2006) reported the stepwise multiple regression for 10 m sprint time from a block start to $R^2 = 0.63$ and %SEE = 2.0. The predictor variable in this formula was CMJ average power (W/kg). Hennessy & Kilty (2001) reported prediction values for a 30 m sprint from a crouch start on female high school sprinters of $R^2 = 0.71$, %SEE = 1.8 and $p < 0.01$. The predictor variables were bounce drop jump and ground contact time. Nesser et al (1996) reported an $R^2 = 0.83$ and %SEE = 2.49 for the 40 meter sprint time of male athletes. The predictor variables were 5-step jump distance, knee flexion peak torque and ankle plantar flexion peak torque.
As can be observed in these studies, the subjects tested, the sprint distance, the predictor variables of interest etc. differ markedly, which makes comparisons between these studies very difficult.

The %SEE values are low in this study (2.3 to 3.3 %), which indicates that the prediction of the sprint speed is very accurate. For the best predictive equation (Eq. 13) ,5-10m sprint time, this means that the predictive sprint time typically is incorrect by 0.018 s (mean 0.74 s).

This %SEE value is only accurate for the same population used in this study, i.e. active males around 22 years old.

Maulder et al (2006) reported a %SEE of 2.0 and Hennessy & Kilty (2001) reports a %SEE of 1.8. However, these studies can not be directly compared to this study because of different population and sprint distance.

A key issue in this study was the landing distance, i.e. how far the feet landed in front of the centre of mass (primarily due to hip and knee angles). This would consequently have affected the jump distance, because it was not the distance that the centre of gravity moved that was measured. The difference in landing technique used by the subjects may have reduced the reliability of the jump distance and therefore reduced the predictive ability of sprint speed.

To reduce this issue it should have been ensured that every subject tested was using a standardised landing technique. A way to standardize this is to instruct the subjects to land with the longest landing distance possible. The positive with this standardization could be that the subject truly can jump as far as possible without any restrictions, but the negative could be that the importance of flexibility of the subjects increases. A second way to standardize the landing technique could be to land almost with straight legs, where the advantage might be that the importance of flexibility decreases, the disadvantage might be that the subject can’t jump maximally for distance, this could affect the subject’s performance psychologically.

Two other findings that potentially could have affected the prediction ability are the takeoff distance and the technique to leave the box. An increased takeoff distance gives the subject potentially a higher start horizontal velocity and it also means that the start position for the centre of gravity is inconsistent among the subjects. The different drop techniques used to leave the box affects the velocity of the centre of gravity, and consequently the stretching (eccentric) phase of the stretch-shortening cycle.

Reliability

The reliability of this jump test is assessed by three important reliability measures; within-trial variations, change in the mean, and retest correlation. (Hopkins, 2000)

The amount of jumps needed (4.49) were close to the lower limit which can indicate that a few subjects could have found a plateau before the limit. The limit level could therefore probably be moved down to three jumps but an upper limit, if needed, of six jumps is recommended.

The lowest within trial variation was found in jump distance with a CV of 1.4% and 1.2% for day 1 and 2, respectively. For most events and tests, the coefficients of variation are between 1% and 5%, depending on things such as the nature of the event or test, the time between tests, and the experience of the athlete. (Hopkins, 2000)

As compared to previous studies of single leg horizontal jump tests this result was found to be similar. For example, Maulder & Cronin (2005) reported CV values of 1.5% for single leg horizontal squat jump and 2.0% for single leg horizontal countermovement jump (single hop for distance). For a horizontal repetitive jump (triple hop for distance) Risberg et al. (2005) reported a CV of 2.2 % and Maulder & Cronin (2005) reported 1.9%.

Compared to research on the reliability of bilateral vertical jumps the SHDJ would seem to have lower within-trial variation. For example, Arteaga et al. (2000) reported CV values of 5.4%, 6.3% and 6.2 % for the squat jump, countermovement jump and drop jump, respectively. Viitasalo & Bosco (1982) reported a within day CV of 5% and 4.3% for squat jump and countermovement jump.

The contact time gives a rough idea of the execution technique of the jump (Aretaga et al, 2000) and the less variation in it shows that similar technique was used for every jump. This study found values of 6.5 % for day 1 and 4.1% day 2 which indicates that the change in technique was quite small. Another observation was that the within trial variation was less in all variables the second day. That could indicate that there was a small learning effect.

In terms of the CV, some scientists have arbitrarily chosen an analytical goal of the CV being 10% or below, but the merits of this value are a source of conjecture (Atkinson and Nevill 1998). All dependent variables fell within the 10% criteria goal. In terms of the new jump test it seems the information gained from multiple trials does not differ greatly from a single trial. The practical application of such findings for jump assessment is that in cases where large numbers of subjects/athletes are being assessed and time is a constraint; only a small number of trials (2-3) are required to gather reliable information. Furthermore in research paradigms where many conditions are being compared order, fatigue, and motivation effects may confound results. In such circumstances the use of a small number of trials would appear acceptable to gather reliable information.

In terms of test-retest reliability, Vincent (1994) classified the ICC as follows; 0.7 to 0.8 is ‘questionable’, >0.9 is ‘high’ and close to one indicates ‘excellent’. The smallest changes in the mean (0.43 %), least variation (< 2.26 %) and an ICC value of 0.95 were found for jump distance. According to Vincent (1994) the ICC value for the new jump test was highly reliable.

The ICC values for this study are similar to those reported in other research of this nature. For example, Maulder & Cronin (2005) who reported ICC values of 0.90 and 0.88 for their single legged horizontal squat jump and horizontal countermovement jump (single hop for distance). Horizontal repetitive jump (triple hop for distance) have also been tested for reliability by

Risberg et al. (1995) (ICC=0.92), Ross et al. 2002 (ICC=0.97) and Maulder & Cronin (2005) (ICC=0.96). ICC values reported by Ross et al. (2002) of 0.92 for single hop for distance, 0.93 for crossover hop for distance and 0.92 for six-meter hop for time. The same jumps were used by Bolgla & Keskula (1997) in their reliability study. The ICC values they reported were 0.96, 0.95, and 0.96, respectively, for the single hop for distance, triple hop for distance and cross-over hop for distance tests. In a study made by Markovic et al. (2004) the test-retest reliability was determined for squat jump (ICC=0.97), countermovement jump (ICC=0.98), standing triple jump (ICC=0.93), standing long jump (ICC=0.95).

The ICC denotes the degree to which individuals maintain their position in a sample with repeated measures. Though there are no preset standards for acceptable reliability measures it has been suggested that ICC values above 0.75 may be considered reliable and this index should be at least 0.90 for most clinical applications (Ellenbecker and Roetert 1995). All ICC values (exception mean VGRF) in the present study, were greater than 0.75 value suggested to denote acceptable reliability. This indicates a high degree of stability between testing days for the procedures and equipment used in this study. These values compare favourably to those cited in previous research concerning new testing procedures (Topp & Mikesky, 1994, Walshe et al., 1996).

Biomechanics

Comparing the biomechanics of sprint running with the SHDJ is a good measure of how well this jump test can simulate the acting forces and the movement pattern in sprint running. Sprint running can be divided into different stages (start, acceleration and maximum speed) with different biomechanical variables being important, however the correlation in this study between the different sprint times (representing these stages) were very high, meaning that although there are obvious differences there are also many similarities.

The fundamental characteristics of the SHDJ are that it is performed on one leg, from a vertical distance and includes both a vertical and a horizontal force component. All these characteristics are equivalent to sprint running.

The SHDJ is performed on one leg, meaning that the stabilisation around the hip is taken in to account. A two foot jump test does not have this ability and could therefore falsely predict an athlete, with bad hip stabilisation, to run faster than he actually does.

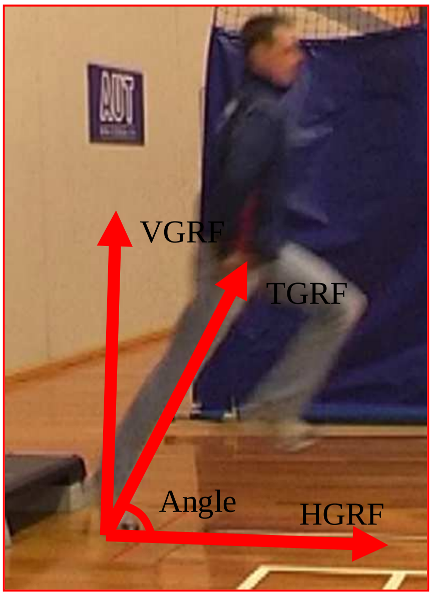

Figure 5: Forces

The starting horizontal velocity of the centre of gravity was standardised to zero in this jump test. This is not valid comparing to maximal running; however it is to the first step. The difficulty concerning a starting velocity is to make it standardised, one attempt was conducted by McIntyre (2005, unpublished) with a poor result.

The jump test was performed from a 20 cm box which gives the athlete a 20 cm drop before performing the jump. This is to simulate the vertical displacement of the centre of gravity which is accruing in sprint running (Hunter et al., 2002), leading to a use of SSC.

It seems that the jump distance is an important measure for predicting speed as it was a significant difference in both 10 meters and 10-25 meters between the top 10 and the bottom 10 subjects. It has also a biomechanical basis that the speed is dependent on the stride length and the stride frequency as the ability to jump far enables the sprinter the possibility to have a longer stride length and as a result an increased speed.

For the 10-25 meters sprint time the peak HGRF from the jump test seems to be important. An explanation for this could be that the ability to produce horizontal force is important for maintaining maximum speed.

For the 10 meters sprint time, the peak VGRF was more important. That could be a result of the larger range of motion used in this type of running and therefore receiving an increased resistance from the body weight. Other important variables seem to be the horizontal and vertical impulse. The appearance of impulse in 10 meters but not in 10-25 meters could be a fact of the length of the contact time compared to flight time; 2:1 during the first acceleration and 1:1.5 during maximum running (Atwater, 1981). The longer contact time gives the impulse more impact.

The peak vertical forces reported in sprint running studies varies from 1.6 N×BW to 3.15 N×BW (Dixon et al., 2000; Hunter et al., 2002; Scholten et al., 2001). Skripko (2003) reports absolute peak VGRF values of 2750 N to 2940 N. These values are then to be compared to this study which reports a vertical force of 1890 N and 2.45 N×BW. This comparison suggests that the attempt of this jump to simulate the vertical forces acting in sprint running is successful.

The takeoff angle is the angle which occurs between the produced force in the propulsive phase and the ground. Coe et al (n.d.) reported a takeoff angle in maximum sprinting of 65.8 (range 60.0-69.8) degrees in their study on female sprinters. The take off angle in this study is reported to 70.9 degrees (mean). Also this comparison of the take off angles between sprint running and this jump test indicates that the jump test simulates sprint running in a good way.

6. Conclusion

Improving assessment is important for improving our understanding of phenomena such as sprint ability and as a result will improve diagnosis/prognosis and subsequently improve programming and ultimately the performance of athletes. With this in mind this study developed and evaluated a single leg horizontal drop jump.

A significant correlation between the single leg horizontal drop jump and sprint speed was found in this study. The combination of jumping distance/height and HGRF explained between 50-72 % of the variance associated with sprint performance over the different distances.
It can be concluded that the intra- and interday reliability of some variables (e.g. jump distance) from the SHDJ test was equal and in a lot of circumstances better than other tests of a similar nature reported in the literature.

To improve the validity of the new horizontal jump in predicting sprint speed for this test protocol there are three factors that need to be controlled to a better extent. These are the landing distance, the take off distance and the technique to leave the box. Different landing distance (different hip and knee angles) affects the measured distance because the centre off mass is not the variable assessed. This factor could be reduced with a standardization of the landing procedure.

The results of this study hopefully will provide information for athletes, coaches and trainers. Such information can be used to: (1) quantify the relative significance of horizontal jumps in predicting athletic performance; (2) identify the specific deficiencies in leg power to improve individual deficiencies (i.e. compare left and right leg scores); (3) identify individuals who may be suited to particular positions; (4) talent identification; and, (5) monitor the effects of various training and rehabilitation interventions.

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Appendices I

Participant Information Sheet

Date Information Sheet Produced:

16 / 03 / 2006

Project Title

Ability and reliability of jump kinematics and kinetics to predict sprinting performance of regional level athletes.

Invitation

You are invited to take part in a research study which seeks to assess four different jumps and sprint speed over 25 m.

What is the purpose of this research?

<u>The aims of this study:</u>

- to determine the reliability of a single leg drop vertical/horizontal jump and single leg VDJ.
- compare the results of a single leg drop vertical/horizontal jump to a single leg VDJ.
- observe the relationship between these two jump assessments and sprint ability.

How are people chosen to be asked to be part of this research?

All subjects are male team sport athletes at a regional or national level. Brochures will be placed on AUT notice boards, so that volunteers can apply.

What happens in this research?

This study will test both jump power and sprint speed. 4 different jumps will be assessed, horizontal and vertical jumps, and with both one and two legs. The jumps will be drop jumps from a box; 15 cm high.

The sprint will be 30 m long, and the time will be recorded at 10 m, 20 m and 25 m.

What are the discomforts and risks?

There is always a certain risk when testing maximal power, e.g. strain a muscle or a distortion of the ankle.

How will these discomforts and risks be alleviated?

These risks will be minimized with a proper warm up, preparation and clear instructions from the researchers.

What are the benefits?

The benefits for the subjects in this study are:

- measure their own jump power and speed
- be a part of an important study, which could improve the way sport scientists measure athletes.

What compensation is available for injury or negligence?

Compensation is available through the Accident Compensation Corporation within its normal limitations.

How will my privacy be protected?

Confidentiality will be maintained throughout this study. No material, which could personally identify you, will be used in any reports on this study. Data collected in this study will be kept in a secure cabinet in a locked office and will be shredded on completion of the study.

What are the costs of participating in this research?

There are no costs to your participation in this study except your time, which will be approximately two hours of testing in total.

How do I agree to participate in this research?

You will need to complete the attached Consent Form if you wish to participate in this study.

Will I receive feedback on the results of this research?

If you wish, at the completion of the study you will be sent a copy of your results and a short summary of the results as a whole. No individuals will be identified in the summary results. The results of this study will also be submitted for publication in an academic journal and for presentation at a national / international conference. It is usual for there to be a substantial delay between the end of the data collection and publication or presentation in these scientific forums.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Justin Keogh, justin.keogh@aut.ac.nz, 09 921 9999 x7617.

Who do I contact for further information about this research?

Researcher Contact Details:

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Auckland University of Technology Ethics Committee, reference number 05/61

Appendices II

Consent to participation in research

Title of Project:

New jump test to predict sprint speed.

Project Supervisor:

Justin Keogh

Researchers:

David Jonsson Holm and Markus Stålbom

I have read and understood the information provided about this research project (Information Sheet dated 16 / 03 / 06.)

- o I have had an opportunity to ask questions and to have them answered.
- o I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- o I agree to take part in this research.
- o I wish to receive a copy of the report from the research: tick one: Yes ○ No ○
- o I wish to receive a copy of my test results: tick one: Yes ○ No ○.

Participant signature: ....……………….

Participant name: ....…………………….

Participant Contact Details (if appropriate):

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Date: ………………....

Auckland University of Technology Ethics Committee, reference number 05/61

Note: The Participant should retain a copy of this form.