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MEASUREMENT TECHNIQUES IN ASSESSING ATHLETIC POWER TRAINING

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Athletic performance can be altered via various training regimens and an important component to increase performance is the intensity of the training stimulus. Plyometric and complex training have been suggested to be useful training methods to improve athletic power, but standardization of techniques to assess training changes can be difficult. Assessments of activity have been made using electromyographic, kinematic, and kinetic measures. Practitioners must be able quantify the effect of their training programs; ideally with measures made in the field. This presentation will review methods to measure outcomes of athletic power training and make suggestions for implementing these measures in the training venue.

KEYWORDS: jumping, reactive strength index, ground reaction force, muscle stiffness index

INTRODUCTION & OVERVIEW: The improvement in performance due to resistance training can be easily quantified because weight training devices usually have clearly labeled masses and thus an athlete's repetition maximum (RM) or 1RM can be established. While resistance training has been shown to improve strength, plyometric training appears to have a greater impact on athletic power (Potach & Chu, 2000). The intensity of plyometric exercises is more difficult to verify, but has been evaluated using many variables including muscle activity, ground and joint reaction forces, number of points of contact during landing, the speed of the drill, the height of the jump, and the athlete's weight as well as other measures (Ebben et al., 2008; Jensen and Ebben, 2007; Potach & Chu, 2000). Some of the measures used in assessing plyometric exercises can also be used to determine gains made from training. Examples of these include vertical jump height, flight time, contact time, reactive strength index, speed strength index, rate of force development, leg spring stiffness, and starting strength (Comyns et al. 2006; Ferris & Farley, 1997; Harrison & Bourke, 2009; McClymont, 2003; Young, 1995).

VERTICAL JUMP HEIGHT: Vertical jump height is an easily obtained measure of performance and while it can be a performance itself (e.g. in high jumping), it has been moderately correlated to sprint and agility performance. Thus additional measures of jumping performance are often used to quantify changes in training.

FORCE MEASURES: Peak force is the highest force obtained during an activity and in jumping activities is usually assessed via ground reaction forces (GRF) on a force platform, but could include forces that take place within the body (e.g. between joints). It can be expressed in absolute terms the raw force obtained in Newtons or scaled relative to body mass (N/Kg). Scaling allows for comparison of different sized individuals as well as to compare force generation across active muscle mass, which can facilitate comparisons across body parts or athletes of widely varying body fat. Peak force is useful in establishing the force the body can exert or the amount of force the body must withstand during landing from jumps (Jensen and Ebben, 2007). The latter while not important in performance can be helpful in determining the risk of injury.

RATE OF FORCE DEVELOPMENT: Through use of a force platform the start of the concentric contraction has been defined as the point where force readings become 10N greater than the average of the force readings when the subject is static in the squat jump starting position (see Figure 1) (Harrison & Bourke, 2009). Maximum Rate of Force Development (max RFD) is then calculated as the greatest rise in force during 5-millisecond periods from the start of the concentric contraction (Wilson et al., 1995; Harrison & Bourke, 2009). Time to peak GRF is calculated by finding the difference in time between the point of the first concentric contraction and peak GRF on the force-time curve (Harrison & Bourke, 2009) and has also been used to estimate the average RFD (Jensen and Ebben, 2007). As most sporting activities require not only a large degree of force, but for it to be generated rapidly, RFD is an important component of sport (Wilson, 1995). Although this time has been used by a number of researchers, it has recently been questioned by Jensen and colleagues (2009) who have noted that simultaneous video analysis indicates the concentric contraction may take place later than this point on the force time tracing. Regardless of when the RFD takes place it has been used as an indication of power production in a variety of movements.

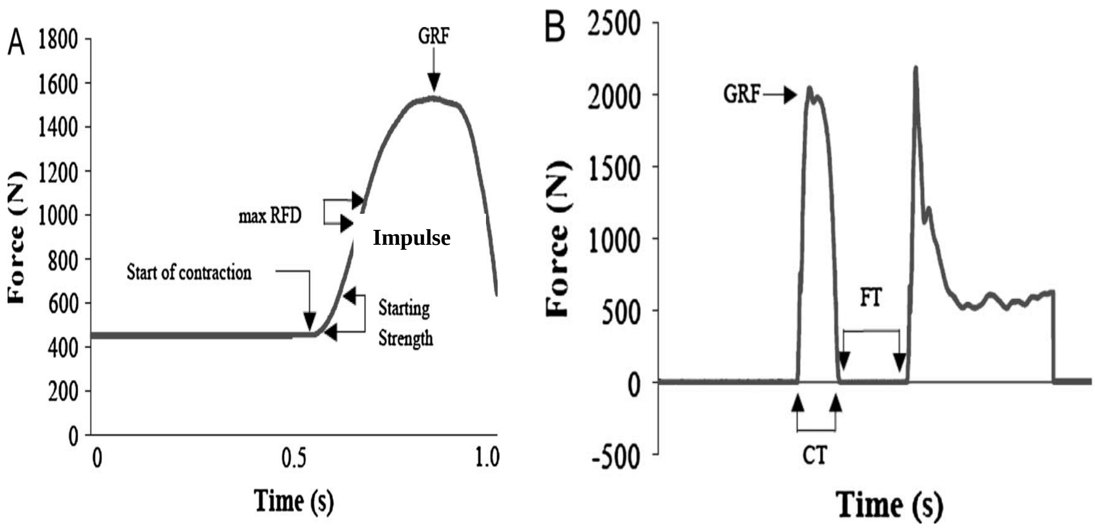

Figure 1. **A) Force-time trace for a squat jump illustrating: start of contraction, maximum rate of force development (max RFD), starting strength, impulse, and peak ground reaction force (GRF); B) Force-time trace for a drop jump illustrating ground contact time (CT), flight time (FT), and ground reaction force (GRF) (adapted from Harrison & Bourke, 2009).**

STARTING STRENGTH: The force produced 30 ms after the start of the concentric contraction (see Figure 1) has been defined as the starting strength and is describes as the ability to produce force very rapidly (Young, 1995). Starting strength has been correlated to initial acceleration and is therefore important for athletes needing to accelerate quickly from a stationary position (Harrison & Bourke, 2009; Young, 1995).

LEG SPRING STIFFNESS: Stiffness of the leg spring in the vertical direction (K_{vert}) has been suggested by Ferris and Farley (1997) to represent the stiffness of the integrated musculoskeletal system during locomotion. As K_{vert} regulates the interaction of the musculoskeletal system and the external environment during the ground-contact phase of locomotion it has been related to running (Ferris & Farley, 1997; Harrison et al., 2004) and hopping/jumping performance (Comyns et al., 2006). K_{vert} is calculated during the ground-contact phase by taking the ratio of the peak vertical ground reaction force (F_{peak}) to the maximum vertical displacement of the center of mass of the body at the instant that the leg spring was maximally compressed (Ferris & Farley, 1997). The measure requires a force platform and double integration of the force or video analysis along with force platform measures. Harrison and colleagues (2004) found that K_{vert} during drop jumps was significantly higher (42%) for national level sprinters compared to endurance runners. Therefore leg stiffness may be an important predictor of sprint ability.

STRETCH SHORTENING CYCLE & CONTACT TIME: In addition to RFD, aspects of the stretch shortening cycle (SSC), the coupling of a rapid eccentric/concentric muscular contraction, can be useful to assess training intensity as well as how the athlete responds to training (Young, 1995). The classification of the SSC as fast (<250 ms) or slow (>250 ms) has also been suggested to be useful in identifying performance in athletes (Schmidtbleicher, 1992). A fast SSC is characterized by a drop jump (DJ), while a countermovement jump (CMJ) illustrates a slow SSC. Harrison and co-workers (2004) obtained an SSC performance index by dividing the subject's respective CMJ or DJ flight time by their average squat jump flight time. Contact time (CT) is defined as the amount of time spent in contact with the ground prior to a jump (Ferris & Farley, 1997). The time of the SSC is determined using the CT following a drop jump. Because the individual is in contact with the ground during a CMJ, contact time cannot be determined for a CMJ. McClymont (2003) notes that determining if an athlete can attain a fast CT may be useful in making suggestions for their training program. Those athletes that need to incorporate more strength into their exercise, such as front line players in rugby, typically display a longer CT and slow SSC; while sprinters and backs in rugby or American football usually exhibit a fast CT and SSC.

REACTIVE STRENGTH INDEX: The reactive strength index (RSI) is calculated by dividing the height jumped by the ground contact time (Young, 1995) and similar to the CT has been used as an indicator of performance. The RSI describes an individual's ability to change quickly from an eccentric to concentric muscular contraction and expresses the athlete's explosive capabilities in dynamic jumping activity (Flanagan et al., 2008). Thus it can provide useful information for coaches of athletes that need to make rapid movements and change of direction. Because CT, RSI, and jump height can be easily obtained using not only force platforms, but also with contact mats or accelerometers and are highly reliable (Flanagan et al., 2008); they can be a valuable tool in assessing athletes' performance. Indeed, McClymont (2003) has noted that RSI testing provides an effective and useful tool in the preparation of elite athletes. Harrison and Bourke (2009) have stated that the relationship of RSI to sprinting performance is similar to that of leg-spring stiffness and sprint performance.

FIELD VERSUS LAB TESTING: As noted above the measures used to assess athletic power performance can be obtained via a force platform. Although this technology will usually be used within a laboratory to insure high reliability, the recent advent of portable force platform devices has allowed these assessments to be brought to training venues. In addition, because they can be used to provide virtually all the measures mentioned in this review, they may be very useful. Never-the-less because these devices typically cost more than $10000, they may be beyond the reach of coaches and strength training practitioners. However, a number of the assessments can be made in the field with less costly alternatives including contact mats, linear position transducers, and accelerometers. In particular contact time, reactive strength index, rate of force development and height jumped (calculated via jump flight time) can be obtained with these tools by using the athlete's mass and acceleration through inverse dynamics. Previous research has shown that measurements using these methods can be reliable within controlled situations (Jennings et al., 2005; McClymont, 2003; Wilson et al., 1997; Young, 1995).

PRACTICAL APPLICATIONS: A variety of measures can be useful in assessing the athlete in the training of athletic power. Because the coach or practitioner in a training venue may be limited by not having extensive equipment, such as a force platform and video analysis that are available in the laboratory setting, alternatives are needed. While vertical jump height can be easily assessed using a jump and reach test with virtually no equipment, this methodology does not allow for more detailed measures. Measurements obtained using contact mats, linear position transducers, accelerometers and force platforms have been used to provide more extensive information on contact time, jump flight time, reactive strength index, rate of force development, and leg spring stiffness, as well as jump height.

REFERENCES:

Comyns, TM, Harrison, AJ, Hennessy, LK, and Jensen, RL. (2006) The optimal complex training rest interval for athletes from anaerobic sports. *J Strength Cond Res 20,* 471–476.

Ebben, W.P., Simenz, C. and Jensen, R.L. (2008) Evaluation of plyometric intensity using electromyography. *J Strength Cond Res 22,* 861-868.

Ferris, DP, and Farley, CT. (1997) Interaction of leg stiffness and surface stiffness during human hopping. *J Appl Physiol 82,* 15–22.

Flanagan, EP, Ebben, WP, and Jensen, RL. (2008) Reliability of the reactive strength index and time to stabilization during plyometric depth jumps. *J Strength Cond Res 22,* 1677-1682.

Harrison, AJ, and Bourke, G. (2009) The effect of resisted sprint training on speed and strength performance in male rugby players. *J Strength Cond Res 23,* 275–283.

Harrison, AJ, Keane, SP, and Coglan, J. (2004) Force-velocity relationship and stretch-shortening cycle function in sprint and endurance athletes. *J Strength Cond Res 18,* 473–479.
Jennings, CL, Viljoen, W, Durandt, J, and Lambert, MI. (2005) The reliability of the FitroDyne as a measure of muscle power. *J. Strength Cond. Res. 19,* 859–863.

Jensen, RL and Ebben, WP. (2007) Quantifying plyometric intensity via rate of force development, knee joint and ground reaction forces. *J Strength Cond Res 21* 763-767.

Jensen, RL, Leissring, SK, Garceau, LR, Petushek, EJ and Ebben, WP (2009) Quantifying the onset of the concentric phase of the force-time record during jumping. *In Proceedings of the XXVII International Symposium of Biomechanics in Sports;* (AJ Harrison, I Kenny, and R Anderson, editors) In Press.

McClymont, D. (2003) Use of the reactive strength index (RSI) as a plyometric monitoring tool. Available at: http://coachesinfo.com/index.php?option=com_content&view=article&id=146:rugby-rsi&catid=47:rugby-general&Itemid=77.

Potach, DH and Chu, DA. (2000) Plyometric training. In: *Essentials of Strength Training and Conditioning.* R.W. Earle and T.R. Baechle, eds. Champaign, IL: Human Kinetics, pp. 427–470.

Schmidtbleicher, D. (1992) Training for power events. In P.V Komi (Ed.) *The Encyclopeadia of Sports Medicine. Vol 3: Strength and Power in Sport* (pp. 169-179). Oxford, UK: Blackwell.

Wilson, GJ, Lyttle, AD, Ostrowski, KJ, and Murphy, AJ. (1995) Assessing dynamic performance: A comparison of rate of force development tests. *J Strength Cond Res 9* 176-181.

Young, W. (1995) Laboratory strength assessment of athletes. *New Stud Athletics 10* 88–96.

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