TAKE-OFF TECHNIQUE IN THE HIGH JUMP

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INTRODUCTION: Many studies have measured the take-off parameters of high jumpers in competition situations. For these measurements to provide useful feedback to the coach, there must be an appreciation of how the parameters are expected to vary with the athlete's strength, standing height, and take-off technique. This paper presents the results of computer simulations that explored these relationships. The results from this work are to be incorporated into a biomechanical analysis program conducted for Athletics Australia. The aim is to improve the performance of Australian high jumpers through relevant and timely biomechanical analysis.

MODEL: Alexander (1990) produced a model of jumping that predicts optimum techniques that are in good agreement with those used by high jumpers and long jumpers. We have refined Alexander's model and are using it to more closely examine the take-off technique in the high jump.

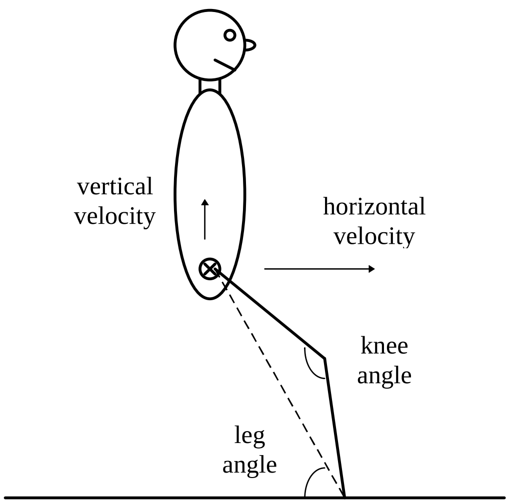

Figure 1 The model used to simulate the take-off phase of the high jump.

In the model, the entire mass of the athlete is concentrated at the hip, and the leg consists of two rigid segments with a total length equal to 53% of standing height (see Figure 1). The contributions to the jumping action of the ankle, knee, and hip joints are combined into a single torque generator at the knee. This torque generator is fully activated while the leg is in contact with the ground, and the torque produced decreases with increasing joint angular velocity according a version of Hill's muscle equation. The muscle parameter values in the model are the same as used by Alexander (1990).

Two "reference" athletes were constructed; an elite male athlete, and an elite female athlete. The body mass, standing height, knee angle at touchdown, and vertical velocity at touchdown were assigned values based on measurements of finalists at recent Olympic Games and World Championships. The jumper's leg strength was adjusted so as to produce a maximum jump height equal to that produced by an elite jumper (male 2.35 m; female 2.01 m).

RESULTS AND DISCUSSION: We considered the sensitivity of the athlete's performance to deviations from the optimum take-off technique by simulating many jumps using systematic changes to the horizontal run-up velocity and leg angle at touchdown. We also examined the dependence of the maximum jump height and the corresponding optimum take-off technique on the athlete's leg strength and leg length.

The dependence of the jump height on the athlete's take-off technique is shown in Figure 2. To maximise the jump height, the male athlete should use a run-up velocity of 7.4 m/s and a leg angle at touchdown of 48°. These optimum values agree with values measured for elite athletes in competition (Conrad and Ritzdorf, 1988). The male athlete has a faster optimum run-up velocity and a lesser optimum leg angle at touchdown than the female athlete, which agrees with the observed gender differences in take-off technique (Dapena et al., 1990).

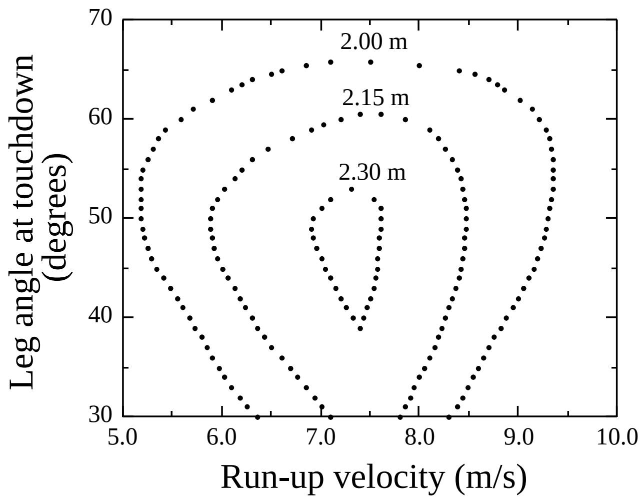

Figure 2 Dependence of the jump height on the take-off technique (reference male athlete).

The jump height is insensitive to moderate changes in the selection of leg angle and run-up velocity by the athlete. To attain within 2 cm of the maximum jump height, the athlete may deviate from the optimum leg angle by about ± 4°, and may deviate from the optimum run-up velocity by ± 0.2 m/s. This amount of variation is similar to the actual variation in the jump height and take-off technique of world-class high jumpers (Greig and Yeadon, 1997), and suggests that coaches need not spend greater attention to having their athletes jump with a more consistent touchdown velocity and leg angle.

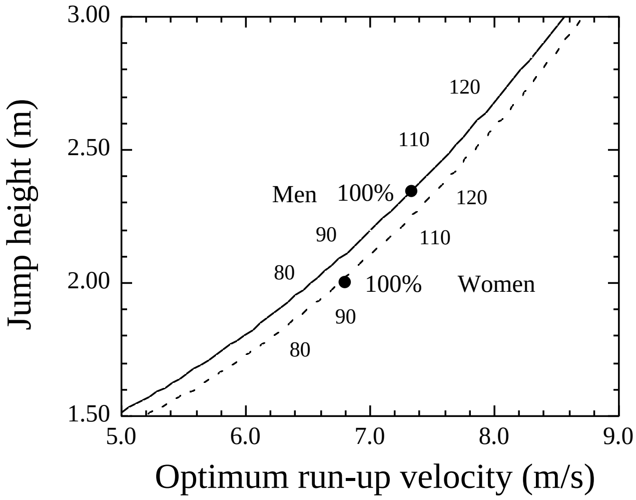

Figure 3 Dependence of the jump height on the athlete's leg strength. The solid circles mark the reference athletes.

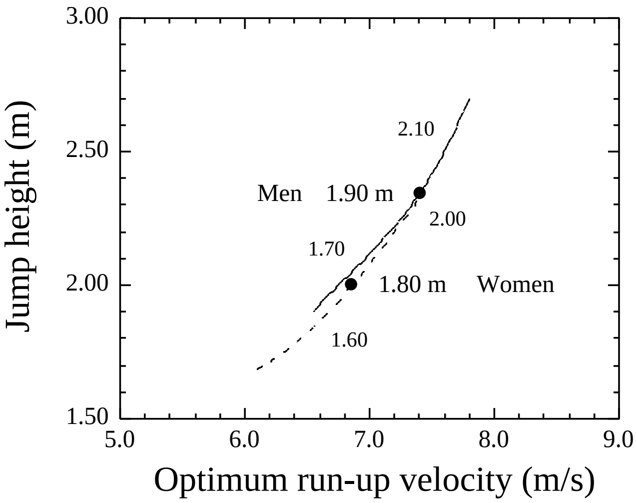

Figure 4 Dependence of the jump height on the athlete's standing height. The solid circles mark the reference athletes.

Figure 3 shows that stronger athletes are able to jump higher and must use a faster run-up. A 5% improvement in jump height (about 10-12 cm) requires a strength increase of 7% and a run-up velocity that is faster by 0.3 m/s. The optimum leg angle at touchdown, however, remains almost unchanged. This finding contradicts the proposal by Dapena et al. (1990) that stronger athletes should employ a markedly lower centre of mass at touchdown.

Figure 4 shows that taller athletes are able to jump higher and must use a slightly faster run-up. The increase in jump height is due to a greater flight height, in addition to a higher centre of mass at take-off.

The results of the simulations indicate that when investigating competition jumps by elite athletes, we should not expect to see strong systematic variations in the run-up velocity and leg angle at touchdown because of inter-individual differences in leg strength and standing height. Any observed variation in leg angle among individuals is probably irrelevant to jumping performance, and is a result of the insensitivity of jumping performance to the precise selection of leg angle by the athlete. A weak dependence of run-up velocity on leg strength is expected, but this will be partly masked by inconsequential deviations from the optimum velocity by the individual athlete. An examination of measurements of athletes competing at recent Olympic Games and World Championships is in progress to test these predictions. The next step in this simulation study is to investigate the effect of the knee angle at touchdown on the optimum take-off technique. Greig and Yeadon (1997) presented experimental evidence that the knee angle may be the take-off parameter that has the greatest influence on jump performance.

Descriptive studies of competition jumps by elite high jumpers have measured the athlete's take-off velocity, take-off angle, take-off duration, and knee bend during take-off. Further simulation studies are planned to investigate the dependence of these parameters on the athlete's leg strength, standing height, and take-off technique. It is also planned to use the model to investigate the effect on jump performance of the athlete's crural index, and of the design of the jumper's shoe.

CONCLUSIONS: This relatively simple model accurately predicts some of the observed relationships between the take-off parameters and jumping performance in elite high jumpers. There is an optimum run-up velocity and leg angle which maximises the jump height, but the athlete's performance is insensitive to moderate deviations from the optimum values. Stronger and taller athletes are able to jump higher and must use a faster run-up. The optimum leg angle at take-off decreases only very slightly with increasing leg strength and standing height.

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