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Physical parameters of the rising kick in taekwon-do

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Summary

Study aim: To find optimum conditions for performing the *twimyo nopi ap chagi* jump.

Material/methods: This paper contains the theoretical description of the test, from the physical point of view.

Results: During the special technique test, the height that the competitor successfully completes, is a sum of 4 heights: the height of the competitor's center of gravity at the moment of the take-off, the change of the height of the center of gravity of the competitor during the flight, and the difference between the highest point of the center of gravity of the competitor and the height at witch the target is suspended. This is shown by the following formula: $H = h_{to} + h_{fl} + \Delta h + h_{kl}$.

Conclusions: The theoretically best angle of take-off for the rising kick is between 65-80 degrees. This angle is necessary to establish the exact spot for the takeoff which will enable the competitor to achieve the best possible result. One must establish this individually for every competitor. The relation between the height of the jump and the force of the takeoff is parabolic; the increase of the takeoff force influences the achieved result.

Key words: **Taekwon-do • Special techniques • Jump assessment**

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Introduction

Every competitor faces the choice of path leading to success and in many a situation a right prediction is the key factor. In order to successfully execute the rising kick (*timyo nopi ap chagi*) at a special techniques competition, the athlete and the coach ought to realise the optimum conditions. Nowadays, the traditional "scissor" technique is becoming obsolete as the "non-scissor" technique has been proven biomechanically superior [2,3]. The aim of this study was thus to present the *nopi ap chagi* jump from the biomechanical point of view.

Methods

The height (H) attained by an athlete performing special techniques is the sum of the following components (Fig. 1):

- Height of the centre of gravity of the athlete at take-off (h_{to}),
- Height of the centre of gravity of the athlete during the flight (h_{fl}),
- Height of the centre of gravity of the athlete during the jump (Δh),
- Height of the centre of gravity gained by stretching the kicking leg (h_{kl}).

These elements were used in preparing a mathematical model of the jump.

Results and discussion

The height at which an athlete breaks the target board can be described by the following equation:

$$H = h_{to} + h_{fl} + \Delta h + h_{kl} \quad (1)$$

A high jump consists of 4 phases: run-up, take-off, flight and landing, each of them depending on different factors (Fig. 2).

The take-off begins at the moment of touchdown of the jump foot during the last stride of the run-up and ends when the jump foot no longer touches the ground, elevating the centre of gravity (COG) to the height h_{fl}. At this moment, the jumper's body is

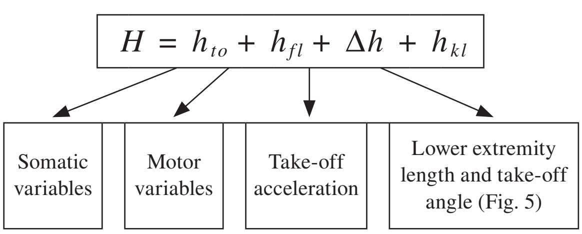

Figure 2. Factors affecting the high jump components.

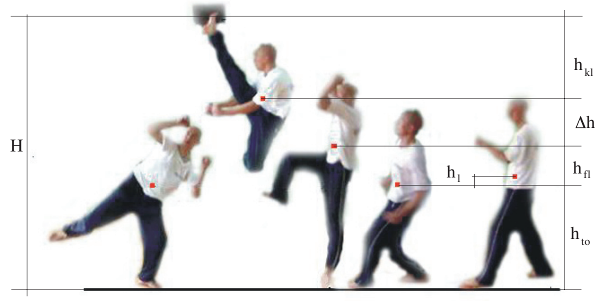

Figure 1. Vertical movement of the centre of gravity along the *OY* axis during the *nopi ap chagi* jump.

accelerating upwards and the height attained by the athlete's COG can be described by the formula:

$$h_{fl} = (v_{OY} \cdot t_{to} + \frac{at_{to}^{2}}{2})$$

where v_{OY} – vertical velocity, t_{to} – take-off duration, a – acceleration attained during the take-off. In the flight phase, the movement is gravitation-decelerated according to the formula:

$$\Delta h = v_{OY} \cdot t - \frac{gt^2}{2}$$

where g – gravity, t – duration of the flight phase.

Formula (1) can now be converted:

$$H = h_{to} + (v_{OY} t_w + \frac{at_{to}^{2}}{2}) + (v_{OY} t - \frac{gt^2}{2}) + h_{kl} \quad (2)$$

The element that undoubtedly affects the jump height is the take-off angle. Knowing that angle, the point of the take-off rendering the best flight height can be precisely determined. The relation between the flight height and the take-off angle, derived from the ballistic equation, is presented below (cf. Fig. 1):

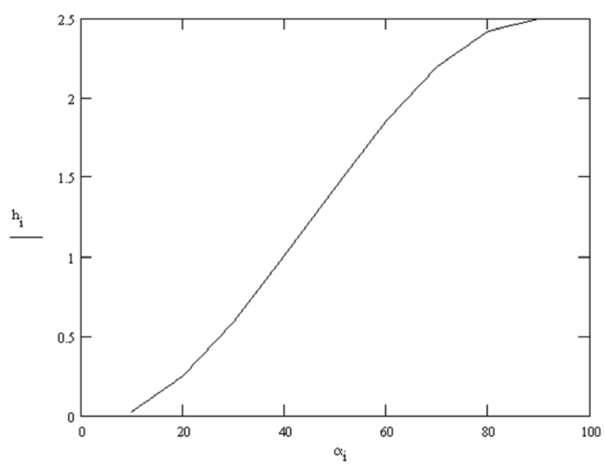

Figure 3. Theoretical relation between the flight height and the take-off angle.

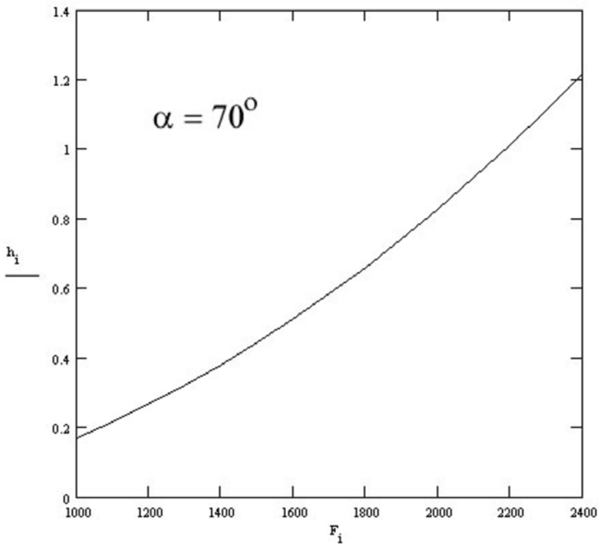

Figure 4. Theoretical relation between the take-off force in a diagonal high jump and the centre of gravity.

Figure 5. The theoretically optimal take-off angle for the *nopi ap chagi* jump.

$$h = \frac{2V_0^2 \sin^2 \alpha - t^2 g^2}{2g} \qquad (3)$$

It follows that an increase in the take-off angle increases the jump height, very high values being attained at take-off angles ranging from 65 to 80º. Above 80º the curve flattens, i.e. an athlete standing almost directly under the target board would not be able to attain a high take-off force.

The take-off force is described by the following equation [1]:

$F_w = R - Q$ (4)

Where R – Ground reaction force at take-off.

$$R = m(g + \frac{\Delta v_y}{\Delta t}) \quad (5)$$

Where Q – Athlete's gravity force.

$Q = m{\cdot}g$ (6)

Based on formula (3), the following parabolic relation between the take-off force and athlete's COG can be obtained (Fig. 4):

$$h = \frac{2(F\frac{t}{m})^2 \sin^2 \alpha - t^2 g^2}{2g} \qquad (7)$$

Summing up, several factors affect the height of the jump. Among them is the individually optimal take-off angle which determines the exact take-off spot, that optimum interval amounting to 65–80º (Fig. 5).

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