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Two-dimensional kinematic and dynamic analysis of a karate straight punch.

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Introduction

The mechanical effect of punches performed in martial arts or boxing sports has been studied on different ways: the impact force was either directly measured with sensors fixed on rigid frames [5, 6] or indirectly estimated from the mechanical features of materials broken during strike tests [2, 3]. A few authors developed experimental devices for measuring this force in actual fighting conditions [1] or on a punching bag [4]. Among the studies that analyzed the kinematics of the striking segments [2, 3, 5], only one [2] related kinematic and dynamic data through the linear momentum. According to this approach, a straight punch struck by a karateka (1.68 m, 68 kg, 3rd dan black belt) on a training instrument traditionally used in karate (*makiwara*) was analyzed in two dimensions.

Material and methods

Anatomical markers were placed on the karateka according to a 12-segment model (Fig. 1), and the scene was filmed at 125 Hz with a high-speed digital camera (Photron Fastcam, PCI series, 521 x 480 pixels). The impact force was measured at a 1 kHz sampling rate by two one-axis force sensors (BETA type N1370, range: 1000 N, sensitivity: 1 N) inserted into a target-block padded with dense synthetic foam and mounted on a flexible composite lath, which was vertically and rigidly fixed on the floor. The subject's total linear momentum (\vec{p}) in the sagittal plane of the galilean reference frame R was calculated (1) by the sum of the linear momenta of the centers of mass (G_i) of the 12 segments weighted

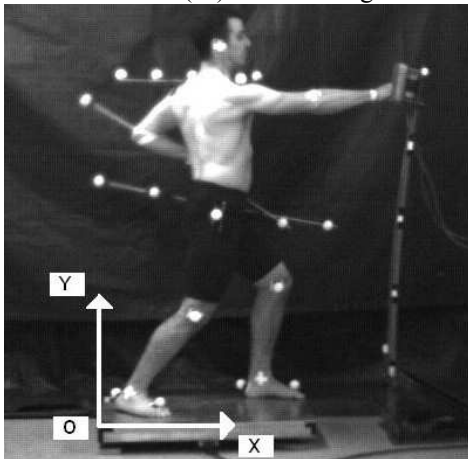


Fig. 1: General view of the experimental setting.

by their respective mass (m_i). The linear impulse (\vec{I}) applied on the target-block was computed by integrating the force values (\vec{F}) measured between the beginning (t_1) and the end (t_2) of contact time (2):

$$\vec{p}(G/R) = \sum_{i=1}^{i=12} m_i \vec{v}(G_i/R) \quad (1) \quad \vec{I}_{[t_1, t_2]} = \int_{t_1}^{t_2} \vec{F} dt \quad (2)$$

Results

The total horizontal linear momentum of the karateka's segments reached a maximum (26,11 kg.m.s⁻¹) before the impact and decreased by 2,58 kg.m.s⁻¹ during the contact time (0,015 s). The peak force (1745 N) measured by the target-block was reached 5 ms after the initial contact and the linear impulse produced during the contact time was 13,7 N.s (Fig. 2).

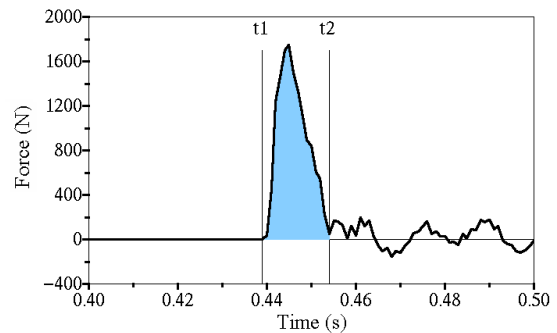


Fig. 2: Time course of the impact force applied on the target-block. The grey area represents the linear impulse between the beginning (t_1) and the end (t_2) of the contact time.

Discussion

The peak force was two to three times lower than the maximum values (4000 to 6000 N) reported in previous studies [1, 5, 6], which could be explained by the *makiwara* flexibility. The large difference between the variation of the karateka's linear momentum and the linear impulse of the target-block pointed out the limitation of a 2-D analysis of this movement, which cannot take into account the angular momenta of the trunk and the upper limbs around the vertical axis.

Conclusion

Although the instrumented *makiwara* still need to be dynamically calibrated, it appeared as a good device for measuring the impact force produced by the karateka. However, a 3-D kinematic analysis is required for calculating the total linear momentum of the karateka's segments actually involved in the punch.

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