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 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 (t1) and the end (t2) of contact time (2):

$$\vec{p}_{(G/R)} = \sum_{i=1}^{i=12} m_i \vec{v}_{(Gi/R)} \quad (1) \qquad \vec{I}_{[t1,t2]} = \int_{t1}^{t2} \vec{F} dt \quad (2)$$

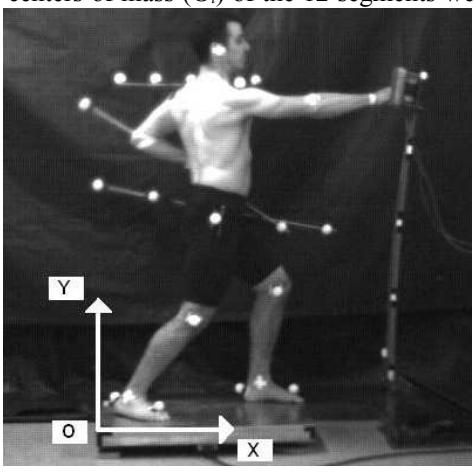

Fig. 1: General view of the experimental setting.

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).

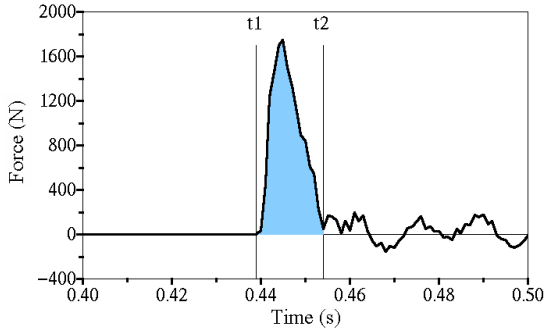

Fig. 2: Time course of the impact force applied on the target-block. The grey area represents the linear impulse between the beginning (t1) and the end (t2) of the contact time.

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.

References

1 – Atha *et al* (1984) *J. Sports Sc.*, **2**, 3: 188-189.
2 – Cavanagh & Landa (1976). *Res. Q.*, **47**, 4: 610-618.
3 – Feld *et a*l (1979) *Scientific Am.*, 240: 110-118.
4 – Fortin *et al* (1993) *XIVth ISB Congress*, 416.
5 – Gottsman (1977) *INSEP dissertation*, Paris (France).
6 – Smith *et al* (2000) *J. Sports Sc.*, 18, 445-450.