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ANALYSIS OF KINETIC ENERGY GENERATED BY THE FRONT KICK (*MAE GERI*) IN ELITE AND SUB-ELITE KARATE ATHLETES

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1 INTRODUCTION

The ability to maximize kinetic energy during movement execution is crucial for impact and effectiveness in combat sports [1]. Assessing how technical efficiency and kinetic coordination influence kinetic energy is essential for understanding performance differences among athletes of varying levels. This study focuses on analyzing the kinetic energy generated during the front kick (*mae geri*) in elite and sub-elite karate practitioners, providing detailed insights into how these factors affect performance in this technique.

2 METHODOLOGY

2.1 SAMPLE

The study involved 14 male karate practitioners (aged 18–35), divided into two groups according to competitive level: Elite (n = 7), with national or international competition experience (age: 26.3 ± 6.9 years; body mass: 77.4 ± 12.7 kg; height: 1.71 ± 0.07 m; body fat: 12.5 ± 6.6%), and sub-elite (n = 7), with regional or state-level competition experience (age: 27.5 ± 6.1 years; body mass: 75.0 ± 8.9 kg; height: 1.71 ± 0.06 m; body fat: 15.1 ± 5.8%).

2.2 DATA COLLETION

Kinematic data during five unilateral frontal kicks were captured using seven T10 cameras operating at 250 fps, along with Vicon Nexus software (Vicon®). Basic Vicon® markers were bilaterally placed according to the Plugin Gait model on anatomical landmarks, including the anterior superior iliac spine, posterior superior iliac spine, lateral femoral condyle, lateral malleolus, Achilles's tendon, dorsal regions of the first and second metatarsals, and midpoints on the lateral thigh and calf. This setup allowed for the analysis of linear and angular displacements, velocities, and power of the upper and lower limbs, and the center of mass during karate strikes.

2.3 ANALYSIS OF THE KINETIC CHAIN IN THE *MAE GERI*

The kinetic chain of the *mae geri* was analyzed by calculating the kinetic energy during hip flexion and knee extension. Kinematic data were processed in MATLAB (v8.0.0.783, MathWorks®, Inc.) and filtered at 6 Hz. Segment masses were estimated using the segmental mass method [2]. The total kinetic chain KE_{MG} was calculated as the sum of the kinetic energy generated by the kinetic energy produced by the anteroposterior linear displacement of the center of gravity KE_{cg}, hip flexion KE_h and knee extension KE_k, as shown in Eq. 1:

$$K_{MG} = KE_{cg} + KE_h + KE_k \quad (1)$$

The kinetic energy produced by hip flexion was determined using Eq. 2:

$$KE_h = \frac{1}{2}(I_h \omega_{R_c}^2) \ (2)$$

Here, I_h represents the moment of inertia of the system driven by the hip, calculated using Eq. 3:

$$I_h = m_{thigh+leg+foot} R_c^2 \ (3)$$

The angular velocity of the hip-driven system ω_{R_c} was the sum of the angular velocity of the hip ω_h and the angular velocity corresponding to the radius of rotation ω_c, as described in Eq. 4:

$$\omega_{R_c} = \omega_h + \omega_c \ (4)$$

The radius of rotation R_c was calculated geometrically using Eqs. 5,6 and Figure 1:

$$R_c = c \ (5)$$

$$c^2 = a^2 + b^2 - 2ab\cos\theta \ (6)$$

and subsequently as:

The kinetic energy generated by knee extension was calculated using Eq. 7:

$$KE_k = \frac{1}{2}(I_k \omega_k^2) \ (7)$$

Here, I_k is the moment of inertia of the system driven by the knee, calculated as Eq. 8:

$$I_k = m_{leg+foot} R_k^2 \ (8)$$

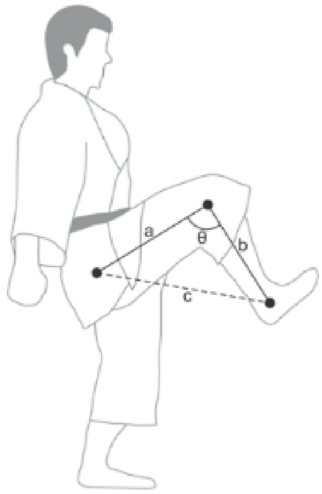

Figure 1. Geometrical model for mae geri.

2.4 STATISTICAL ANALYSIS

The Shapiro-Wilk test was used to assess normality, and independent samples t-tests were conducted to compare peak kinetic energy between elite and sub-elite athletes ($p < 0.05$). Effect sizes were calculated using Cohen's d (d), with d = 0.2 indicating a small effect, d = 0.5 a medium effect, and d = 0.8 a large effect.

3 RESULTS

The independent samples t-test revealed a significant difference in peak kinetic energy between elite and sub-elite karate athletes ($p = 0.01$). Elite athletes exhibited higher values (155 ± 54 J vs. 124 ± 34 J), with a moderate effect size (d = 0.69). These results suggest superior biomechanical efficiency and motor control in elite athletes.

4 CONCLUSIONS

Elite athletes demonstrate greater final kinetic energy during the *mae geri*, a result of superior technical efficiency and optimized kinetic chain coordination. These findings highlight the critical role of biomechanical optimization in enhancing karate performance, offering a foundation for developing targeted training programs aimed at improving energy transfer and technical execution in combat sports. Nevertheless, the cross-sectional nature of this study limits the ability to assess temporal or training-induced changes, underscoring the need for longitudinal research to deepen our understanding of skill development.

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