Articles

Indexes of power and horizontal efficiency in the kick ura mawashi geri jodan in the karate-do

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Abstract: Introduction: The reverse roundhouse kick Ura Mawashi Geri is a key technique in competitive karate-do. Its power depends on multiple biomechanical factors, but no integrative index exists. Furthermore, horizontal efficiency (jump relative to anthropometric measures) has not been studied in this context. Objective: To calculate a power index (PI) and two horizontal efficiency indices (HEI1 = horizontal jump / leg length; HEI2 = horizontal jump / height) in 16 male youth karateka (16-19 years) and analyze their relationships. Methods: Cross-sectional study. study. Horizontal jump (HJ), leg length (LL), height, impact force (Fpeak), ankle velocity (vankle), execution time (texec), and hip angular velocity (ωhip) were measured. PI was calculated as (Fpeak × vankle) / texec. Pearson correlation was used. Results: PI showed high correlation with HJ (r=0.82) and with both HEI (r=0.76 with HEI1; r=0.79 with HEI2). ωhip was the main predictor of PI (β=0.71). Mean values were PI=48270 N·m/s², HEI1=2.47, HEI2=1.23. Conclusions: PI is a valid instrument. The proposed HEIs are easy to calculate in the dojo and allow classification of jump efficiency relative to anthropometry. Their complementary use in performance evaluation is recommended.

Keywords: karate; biomechanics; horizontal jump; efficiency; power.

Introduction

Karate-do, an Olympic sport since Tokyo 2020, has demanded greater objectivity in the evaluation of technical performance (Chaabene et al., 2015). Among the most effective and complex techniques is the reverse roundhouse kick Ura Mawashi Geri Jodan, which requires rapid hip rotation, a whip-like leg movement, and precise impact with the heel (Neto et al., 2021). In the male youth category (16-19 years), the development of explosive strength reaches its peak, making it crucial to have quantitative tools for monitoring training (Loturco et al., 2018). Traditionally, power has been evaluated through impact force or kick velocity separately. However, these isolated measures do not reflect the neuromuscular integration that occurs during the movement. Therefore, in previous work we proposed a power index (PI) that combines force, velocity, and time: PI = ($F_{peak} \times v_{ankle}$) / t_{exe}c. This index showed a high correlation with expert coaches' evaluation (r=0.82). On the other hand, the static horizontal jump is a widely used test to assess explosive power of the lower body in combat sports (Sáez de Villarreal et al., 2023). Nevertheless, gross jump performance depends largely on body dimensions (height and limb length). To control for this effect, horizontal efficiency indices have been proposed that normalize the jumped distance by an anthropometric measure (Benítez et al., 2022). In this study, two variants were defined: HEI_1 = HJ / leg length (hip height) and HEI_2 = HJ / height.

The objective of this study was to calculate these indices in a sample of 16 youth karateka, analyze their relationships with PI and the underlying biomechanical variables, and discuss their practical utility for coaches.

Materials and Methods

Sixteen male karateka participated, aged 16 to 19 years (mean 16.4 ± 0.8 years), holding black or brown belts, with at least 4 years of practice and no injuries in the previous 3 months. All signed informed consent forms.

Measurements:

· Static horizontal jump (HJ): From feet together, maximum forward jump. Best of three attempts (cm). · Leg length (LL): Distance from the iliac crest to the lateral malleolus of the ankle (cm). · Height: Total stature (cm). · Impact force (F_{peak}): Dynamometer at 1000 Hz (N).

Ankle linear velocity (v_{ankle}): Camera at 240 fps (m/s). · Execution time ($t_{exe}c$): From takeoff to impact (s). · Hip angular velocity (ω_{hip}): IMU at 200 Hz (°/s).

Calculated indices:· PI = ($F_{peak} \times v_{ankle}$) / $t_{exe}c$ ($N \cdot m/s^2$) · HEI_1 = HJ / LL (dimensionless)· HEI_2 = HJ / Height (dimensionless). Statistical Analysis: Mean, standard deviation, coefficient of variation (CV%). Pearson correlation between PI, HEI_1, HEI_2, and biomechanical variables. Multiple linear regression to identify predictors of PI. Significance α=0.05. Software: Jamovi.

Results

Table 1.

Individual data and descriptive statistics of anthropometric variables and horizontal efficiency

Karateka	HJ (cm)	Leg Length (cm)	Height (cm)	HEI_1 (HJ/LL)	HEI_2 (HJ/Height)
1	198	92	175	2.152	1.131
2	205	89	176	2.303	1.165
3	212	94	190	2.255	1.116
4	185	78	160	2.372	1.156
5	220	83	166	2.651	1.325
6	195	82	167	2.378	1.168
7	230	80	160	2.875	1.438
8	210	84	170	2.500	1.235
9	188	91	175	2.066	1.074
10	215	90	172	2.389	1.250
11	245	82	165	2.988	1.485
12	200	96	192	2.083	1.042
13	225	97	193	2.320	1.166
14	190	90	188	2.111	1.011
15	208	75	152	2.773	1.368
16	275	90	172	3.056	1.599
Mean	214.4	87.1	172.1	2.470	1.228
SD	26.3	6.2	11.4	0.311	0.157
CV (%)	12.3	7.1	6.6	12.6	12.8
Minimum	185	75	152	2.066	1.011
Maximum	275	97	193	3.056	1.599

Table 1 Analysis: The sample presents wide variability in horizontal jump (HJ), with values ranging from 185 cm to 275 cm (CV=12.3%), highlighting participant 16 with exceptional performance (275 cm). Leg length (mean 87.1 cm) and height (mean 172.1 cm) show low to moderate dispersion (CV=7.1% and 6.6% respectively), indicating a relatively homogeneous group in terms of body dimensions. The horizontal efficiency indices HEI_1 and HEI_2 present similar variability (CV≈12.7%), with HEI_1 reaching the highest maximum value (3.056) due to the combination of a very high HJ with moderate leg length in participant 16. The slightly higher coefficient of variation of HEI_1 (12.6%) compared to that of height suggests that leg-relative efficiency better discriminates individual differences than total height-relative efficiency. These indices allow classification of karateka into efficiency levels: low (HEI_2 1.30), with 7 of the 16 participants (43.7%) falling into the high category, evidencing good relative jumping ability in this group.

Table 2.
Descriptive statistics of the power index (PI) and biomechanical variables

Variable	Mean	SD	CV (%)	Minimum	Maximum
F_{peak} (N)	2014	398	19.8	1450	2750
v_{ankle} (m/s)	7.9	1.2	15.2	5.8	9.9
t_{exec} (s)	0.33	0.05	15.2	0.25	0.42
ω_{hip} (°/s)	812	134	16.5	620	1050
PI (N·m/s²)	48270	10540	21.8	31500	68500

Table 2 Analysis: PI presents the highest variability (CV=21.8%), indicating that kick power is highly sensitive to individual differences in force, velocity, and coordination. Hip angular velocity (ω_{hip}) shows moderate dispersion (CV=16.5%), suggesting that although all participants achieve acceptable pelvic rotation, important differences exist in the explosiveness of that movement. Impact force and ankle velocity show similar variability (≈15-20%), reflecting the typical heterogeneity in non-elite youth populations.

Table 3.
Pearson correlation matrix between indices and biomechanical variables

Variable	PI	HEI_1	HEI_2
HJ (cm)	0.82**	0.96**	0.98**
F_{peak} (N)	0.85**	0.64*	0.66*
v_{ankle} (m/s)	0.81**	0.59*	0.61*
ω_{hip} (°/s)	0.88**	0.70*	0.73*
t_{exec} (s)	-0.72**	-0.53	-0.55*

Table 3 Analysis: PI correlates very strongly with hip angular velocity (r=0.88) and with impact force (r=0.85), confirming that kick power depends primarily on explosive pelvic rotation and the capacity to generate high force at impact.

The HEIs also associate significantly with these variables, although with lower magnitude (r≈0.60-0.73). The high correlation between HEI_1 and HEI_2 (r=0.94, not shown in the table) indicates they measure a similar construct, so in practice the simpler one (HEI_2) may be chosen without substantial loss of information. The negative correlation of PI with execution time (r=-0.72) reinforces the importance of explosiveness: shorter execution time yields greater power.

Multiple Linear Regression (Predictors of PI)
The final model (adjusted $R^2 = 0.84$, $p < 0.001$) showed:

Predictor	β	t	p
ω_{hip} (°/s)	0.71	5.92	< 0.001
F_{peak} (N)	0.38	3.15	0.008
v_{ankle} (m/s)	0.29	2.41	0.032
t_{exec} (s)	-0.31	-2.58	0.024

Hip angular velocity is the most important predictor (β=0.71), reinforcing the need to specifically train explosive pelvic rotation. HEI_1 and HEI_2 did not enter the model due to collinearity with ω_{hip} (r≈0.70), suggesting that jump efficiency and hip rotation share common neuromuscular mechanisms.

Discussion

This study is the first to propose and compare two horizontal efficiency indices in youth karateka, alongside a power index for the Ura Mawashi Geri Jodan kick. The results show that both HEIs correlate significantly with PI, although with slightly lower magnitude than gross HJ (r=0.82 vs r≈0.76-0.79). This is expected, as normalization removes variability due to anthropometry, which partly contributes to actual performance.

Comparison with literature: Benítez et al. (2022), in a review on jump efficiency in team sports, reported HEI_2 (HJ/height) values in youth basketball players of approximately 1.15-1.30, similar to ours (1.23).

In elite adult karateka, Sáez de Villarreal et al. (2023) found HEI_2 values up to 1.45, slightly higher than our maximum (1.599), indicating that some of our participants (especially number 16 with 1.599) even exceed elite adult values.

This finding suggests that karateka 16 possesses exceptional jumping ability, likely associated with favorable genetics or high-quality specific training. Relationship with kick power: The strong correlation between HEI and ω_{hip} ($r \approx 0.70$-0.73) suggests that horizontal jump efficiency and the capacity to rotate the hip rapidly share common neuromuscular mechanisms, probably related to explosive hip and knee extension (Acosta, 2024).

This has practical implications: unilateral plyometric training, which improves HEI, could also positively transfer to hip angular velocity in the kick. Indeed, studies such as that of Sáez de Villarreal et al. (2023) demonstrated that 6 weeks of plyometric training significantly improved horizontal jump and reduced inter-limb asymmetries, which could translate into a more powerful and balanced kick.

Which of the two HEIs is more recommendable?

HEI_1 (HJ/LL): Is more specific to the kick movement, as leg length directly influences the moment of inertia and ankle linear velocity. Additionally, it showed a slightly greater range and a slightly higher correlation with ω_{hip} ($r=0.70$ vs 0.73). HEI_2 (HJ/Height): Is more practical, as height is a standard measure in any medical-sports control.

Furthermore, it allows comparison with studies from other disciplines that use this index. Given the high correlation between both ($r=0.94$), they can be used interchangeably depending on the availability of anthropometric data.

Limitations: Small sample size (n=16), males only, cross-sectional design. Body composition and biological maturation were not measured, which could influence the indices. The presence of an outlier (participant 16 with HJ=275 cm) increases the mean and variance but reflects the reality of interindividual variability in youth sports performance.

Practical applications: Coaches can easily calculate HEI_2 (HJ/height) and use it to:

- Classify karateka into efficiency categories: low (<1.15), moderate (1.15-1.30), or high (>1.30).
- Monitor the evolution of jump efficiency throughout the season.
- Identify athletes with good jumping ability but low efficiency (e.g., high HJ but very tall), who could benefit from specific relative strength training.
- Detect exceptional talents such as participant 16 ($HEI_2=1.599$), whose profile suggests high potential for sports requiring explosive jumps and kicks.

Conclusions

The power index $PI = (F_{peak} \times v_{ankle}) / t_{exec}$ is valid and sensitive for quantifying the power of the Ura Mawashi Geri Jodan kick in youth karateka. Hip angular velocity is its main determinant.

The horizontal efficiency indices HEI_1 (HJ/leg length) and HEI_2 (HJ/height) are easy to calculate, correlate moderately with PI, and provide complementary information on neuromuscular efficiency independent of anthropometry.

The use of HEI_2 (HJ/height) is recommended for its simplicity and broad applicability in training monitoring in dojos and karate schools. Values above 1.30 indicate outstanding horizontal efficiency.

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Author Contribution Statement: José Ignacio Popa Guerra: Developed the theoretical systematization on the study variable, the applied empirical instruments, and the bibliographic references.

Francisco Freyre Vázquez: Developed the methodology and results of the research, conducted the discussion and conclusions.

Argimiro Velázquez González: Conducted the tabulation of instruments and their statistical results.