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Application of force-velocity cycle ergometer test and vertical jump tests in the functional assessment of karate competitor

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Aim. The aim of this study was to analyze the links between tests performances (vertical jump and force-velocity sprint on cycle ergometer) and 2 different karate level groups in order to propose a test battery adjusted to karate.

Methods. Twenty-two karate competitors (10 national junior team (IJ) and 12 national competition level (NL)) performed 4 maximal squat jumps (SJ), 4 maximal counter movement jumps (CMJ) on an ergojump and 3 8-s sprints on a friction braked cycle ergometer (friction loads of 0.5, 0.7, 0.9 $N \cdot kg^{-1}$). The maximal theoretical force (F_0) and velocity (V_0), the maximal power output (P_{max}) and the optimal pedalling velocity (V_{opt}) were derived from both the force — velocity and the power — velocity relationships plotted from all the 3 friction loads data. V_0, F_0, V_{opt}, P_{max} and the best SJ and CMJ, were compared between IJ and NL groups.

Results. The IJ group was characterised by significantly higher values of V_0 (+13%) and SJ (+14.3%) compared to NL group, whereas no significant difference was observed between groups for F_0. Thus, karate performance would depend on maximal velocity and explosive strength. In addition, V_{opt} was significantly higher in IJ group compared to NL group (135.4 rpm *vs* 119.2 rpm, $p<0.001$). Although based upon indirect evidence, these results accounted for mechanical functional capabilities of experts which could be particularly valuable when monitoring training of karate competitor.

Conclusion. A force-velocity and a vertical jump tests may be applied in the functional assessment of karate competitor.

KEY WORDS: Muscle, skeletal, physiology - Martial arts - Movement, physiology.

Karate consists of many repetitions of short-term and strenuous exercises in sparring matches.[1] In competition the best mean to gain the victory involves striking first performing selected technical combinations such as punching or kicking. Karate practitioners fight from a preferred offensive or defensive behaviour. In the former, the assailant takes the initiative to make the distance shorter and to strike rapidly. The defender forestall the opponent's actions in order to dodge and afterwards to counter. Therefore, swiftness in the shifting displacements should be an extent element of performance. Few studies have been conducted to document in muscular mechanical characteristics of karate practitioners [2-4] particularly regarding lower limbs. Because hip and knee extensors are fundamental for karate stepping, an horizontal specific leaping test would be relevant to explosive karate movement. However, to the best of our knowledge no

The experiments comply with the current laws (Arrêté du 28 avril 2000 fixant la nature et la périodicité des examens médicaux assurés dans la cadre de la surveillance medicale des sportifs de haut niveau) of my country in which the experiments were performed.

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TABLE I.—*Age, anthropometric characteristics and maximal oxygen consumption of the subjects.*

Groups	Age (years)		Height (cm)		Body mass (kg)		Body fat (%)		$\dot{V}O_{2max}$ (ml·min^{-1}·kg^{-1})	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total (n=22)	22	3	177.2	7.4	70.3	10.9	13.3	4	57.8	3.6
IJ (n=10)	20.1	1.1	178.7	7.8	71.3	11.9	13.1	4.4	57.2	4.1
NL (n=12)	24	3	175.7	7.1	69.2	10.4	13.4	3.8	58.5	3

Body fat was determined using the method of Durnin *et al.*[19]
Total: total group, IJ: international junior group and NL: national level group.

suitable test is available to account for performance in karate. It was hypothesised that explosive strength, muscle elastic properties and maximal velocity may be the major muscle mechanical factors involved in karate performance.

The choice of the most appropriate test to predict the performance for a sport speciality is difficult. Therefore, the non-specific force-velocity on a cycle ergometer and vertical jump tests have often been selected in studies [5-9] conducted to relate test performances to the sport speciality. The rationale of the used tests for the functional assessment of competitors performing horizontal displacements was provided recently by Morin *et al.*[7] who showed that the maximal power generated on a cycle ergometer during force-velocity test was significantly related to the acceleration phase (between 5-10 m) of a sprint start in trained male athletes.

The friction loaded cycle ergometer was often used [5, 9-14] in order to analyze the muscle mechanical characteristics through the force-velocity and power-velocity relationships. The literature has reported different methods for analysing the force-velocity relationship. Arsac *et al.*[10, 11] have analyzed the relationship between the instantaneous pedalling velocity and the force (sum of the friction force and the flywheel inertial force) generated during the acceleration phase. It was reported from the different methods of analyzes [9, 10] that during a 10-s sprint exercise, the relationship between force and pedalling velocity was linear. Power output and pedalling rate have been linked by a relationship which can be expressed as a parabolic function.[10, 11] Maximal values of force and pedalling velocity, maximal power output and optimal pedalling velocity were presented as individual muscles characteristics in the previous studies.

Mechanical characteristics of leg extensor muscles have been also estimated in the literature from vertical jump tests,[5, 6, 9, 15] particularly with the test protocol described by Bosco.[6] Maximal squat jump (SJ, cm) was used to estimate the explosive strength.[6] In addition, stretching an active muscle prior to its shortening enhances its performance.[16-18] Thus, counter movement jump (CMJ, cm) was performed to allow for a comparison with SJ.[15, 16]

The aim of this study was to reveal differences in mechanical variables between 2 different karate level groups (international *vs* national) from force-velocity and vertical jump tests. Moreover the links between tests performance and tactical choice (offensive vs defensive behaviour) were analyzed with braking down the two skill levels into attacking propensity.

Materials and methods

Subjects

Twenty-two male karate competitors (total) participated in this study carried out at the French Karate Federation's request. Ten were members of the French junior national team (IJ) and 12 were at national level of competition (NL). IJ and NL groups gathered 8 assailants and 2 defenders and 4 assailants and 8 defenders, respectively. Therefore, the total group was divided according to the offensive (OB) and defensive (DB) athletes' behaviour. The characteristics of the subjects were reported in Table I. Written informed consent was obtained from each subject in accordance with policies of the French Karate Federation.

Protocol

The test began with a 6-min cycling warm-up from 1-min at 1 W·kg^{-1} and 5-min at 2 W·kg^{-1}. Each subject performed 4 SJ and 4 CMJ with 1-min recovery between the trials. The SJ and the CMJ tests protocol have been previously described by Bosco.[6] After 5-min of recovery period the subject performed 3 8-s sprints on a friction braked ergometer with a 5-min recovery period between the sprints. Friction load on the flywheel of 0.5, 0.7 and 0.9 $N \cdot kg^{-1}$ body mass were applied. Each friction load determined a propulsive force (F, N) applied on the pedal dependant of the pedalling rate. The sprints were performed with standard pedals without toe-clips in order to only measure the activity of the lower-limb extensor muscles.[20] The start position on the cycle ergometer was standardised: the subject was seated on the saddle during the sprint and started the exercise with his preferred leg, the crank located at 45° forward. The subject was vigorously encouraged during the tests.

Material and calibration procedure

The height of the vertical jumps was measured from the Ergojump device (Junghans GMBH-Schramberg, BRD): the flight time of each vertical jump was measured with an electronic apparatus. A digital timer (Psion II) was connected by a cable to a resistive platform. The timer was triggered by the feet of the subject and the flight time was measured.[21]

The friction braked cycle ergometer (Monark 818 E) was instrumented with the SRM Training System (Schoberer Rad Messtechnik, Königskamp, Germany) extensively tested.[22] The mechanical power output (measured on the crank gear) (P, W) and the pedalling rate (V, rpm) were measured at 10 Hz from the total duration of the 8-s sprint with a precision of ±0.5%. The calibration procedure of the SRM dynamometer was performed before each test according to the manufacturer recommendations. The calibration of the belt tension was performed according to the subject's mass at 50 rpm pedalling cadence. The tension of the belt was considered optimal when the theoretical mechanical power (P_{th}, W) computed from the equation (1) was reached on the SRM' screen display.

$$P_{th} = Ff \cdot V \cdot 6.13 \qquad (1)$$

where Ff (N) was the friction force applied on the flywheel, V (rps) the pedalling velocity and 6.13 (m) the distance of the flywheel for every complete revolution of the pedal.

Mechanical variables measured

The propulsive force (F, N) applied on the pedal was computed from the equation (2):

$$F = \frac{P}{L \cdot V} \qquad (2)$$

where L (0.175 m) was the length of the crank and V was expressed in $rad.s^{-1}$. The V (rpm) F (N) and the V (rpm) P (W) relationships were analyzed from all the 3 friction loads data according to the Arsac method.[10, 11] The velocity values (and the corresponding force values) lower than 100 rpm were not taken into account for the V-F relationship.[10, 11, 23] Maximal theoretical force F_0 ($N \cdot kg^{-1}$) and velocity V_0 (rpm) were defined from the extrapolation of the linear regression between V and F. The V P relationship was fitted with a 2nd order polynomial regression.[13, 14] At the top of the curve corresponds the maximal power output (P_{max}, W) and the optimal pedalling velocity (V_{opt}, rpm). V_{opt} was determined by a mathematical derivation of the V *P* regression equation and P_{max} was calculated from this equation. The power meter values were analyzed in Excel file.

The best trial performed in SJ and in CMJ was analysed. Muscle elastic properties was assessed from the difference between CMJ and SJ (Δ_{CMJ-SJ} = CMJ SJ).[15, 16]

Statistics

The variation coefficient (CV) (CV = SD/mean) was calculated for all the mechanical variables. The V-F and the *V-P* relationships were tested from a regression analysis. Relationships between mechanical variables (SJ, CMJ, V_0, F_0, P_{max} and V_{opt}) were tested from a correlation analysis in the total group. A Mann-Whitney test was used to compare the data obtained in the i) IJ and NL groups ii) OB and DB subgroups. The level of significance was set at $p<0.05$.

Results

The relationship between V and P was fitted by a 2nd order polynomial equation ($r^2 = 0.610$-0.959, $p<0.001$) (Figure 1). For all subjects a significant linear relationship was observed between V and F (Figure 2).

Comparison between IJ and NL groups

The mean values and standard deviations of the different variables for the IJ and NL groups are presented in Table II.

The significant differences observed between IJ and NL groups for SJ, V_0, V_{opt} and P_{max} were presented in Figure 3A-D, respectively. No significant difference

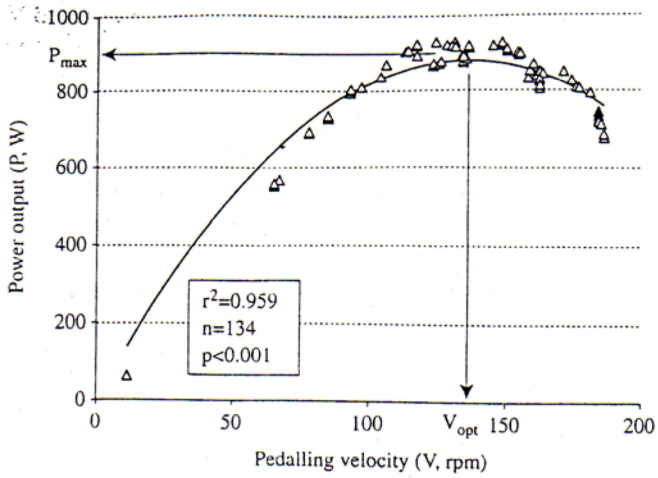

Figure 1.—Typical velocity-power relationship determined in a subject during 3 8-s sprints (0.5, 0.7, 0.9 N·kg-1). The arrows indicated the maximal power reached (P_{max}) and the corresponding optimal velocity (V_{opt}).

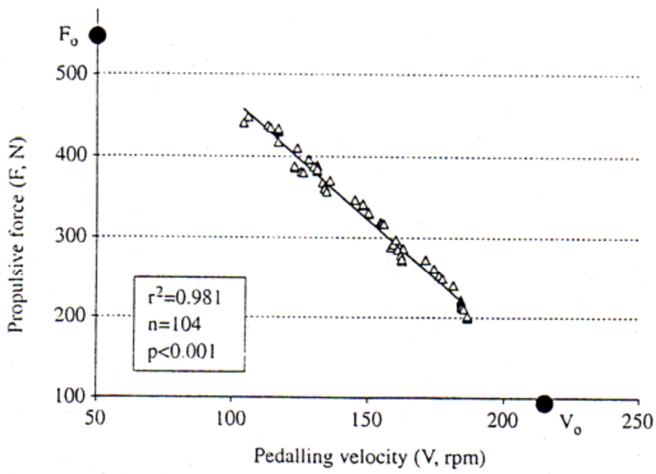

Figure 2.—Typical velocity-force relationship determined in a subject during 3 8-s sprints (0.5, 0.7, 0.9 N·kg-1). The filled circles indicated the maximal theoretical velocity (V_0) and the maximal theoretical force (F_0).

was found between IJ and NL groups concerning CMJ, Δ_{CMJ-SJ} and F_0(related to body mass). A positive relationship was observed between V_{opt} and V_0 for the IJ (r=0.968, p<0.001) and NL (r=0.773, p<0.01) groups.

Comparison between OB and DB subgroups

Compared to the OB subgroup, the DB subgroup showed lower values of SJ (35.7±2.6 cm *vs* 42.4±4.3 cm, p<0.001), CMJ (39±3.2 cm *vs* 44.9±5.4 cm, p<0.01) and V_{opt} (121.8±11 rpm *vs* 130.5±11.2 rpm, p<0.05). However, no significant difference was found between OB and DB subgroups concerning ΔCMJ-SJ, F_0,V_0 and P_{max} (related to body mass).

Mechanical variables for the total group

The mean values and standard deviations of the different variables for the total group are presented in Table II. Table III shows correlation matrix between the results of the different tests.

Discussion

Comparison between international and national level groups

The most important finding of this study was the higher V_0 (+13%), V_{opt} (+13.6%), P_{max} (+14.7%) and SJ (+14.3%) observed in IJ group compared with NL group (Figure 3A-D). These results suggest that force-velocity and squat jump tests could reveal different mechanical functional capabilities between 2 skill level groups in karate competitors. Among these evidences, V_0, V_{opt} and SJ variables would be relevant with swiftness and explosive actions involved in karate, although specific displacements are horizontal stepping. The lack of significant difference observed between groups for F_0 could suggest that karate dis-

TABLE II.—*Mechanical values (mean±SD) generated on force-velocity and vertical jump tests.*

Groups	SJ (cm)	CMJ (cm)	Δ_{CMJ-SJ} (cm)	V_0 (rpm)	F_0 (N·kg-1)	P_{max} (W·kg-1)	V_{opt} (rpm)
Total (n=22)	39.4±4.9	42.2±5.4	2.8±2.1	256.7±18.7	10.2±1	11.6±1.6	126.5±11.7
IJ (n=10)	42.3±4.8	44.9±5.9	2.6 ±2.1	263.1±15.9	10.3±1.1	12.5±1.3	135.4±5.6
NL (n=12)	37±3.6	40±3.8	3±2	232.8±13.7	10.1±1	10.9±1.5	119.2±10.4

The height of squat jump (SJ) and counter movement jump (CMJ), the maximal theoretical velocity (V_0), the maximal theoretical force (F_0), the optimal velocity (V_{opt}) and the maximal power output (P_{max}) measurements of the total group (Total), the international junior group (IJ) and the national level group (NL).

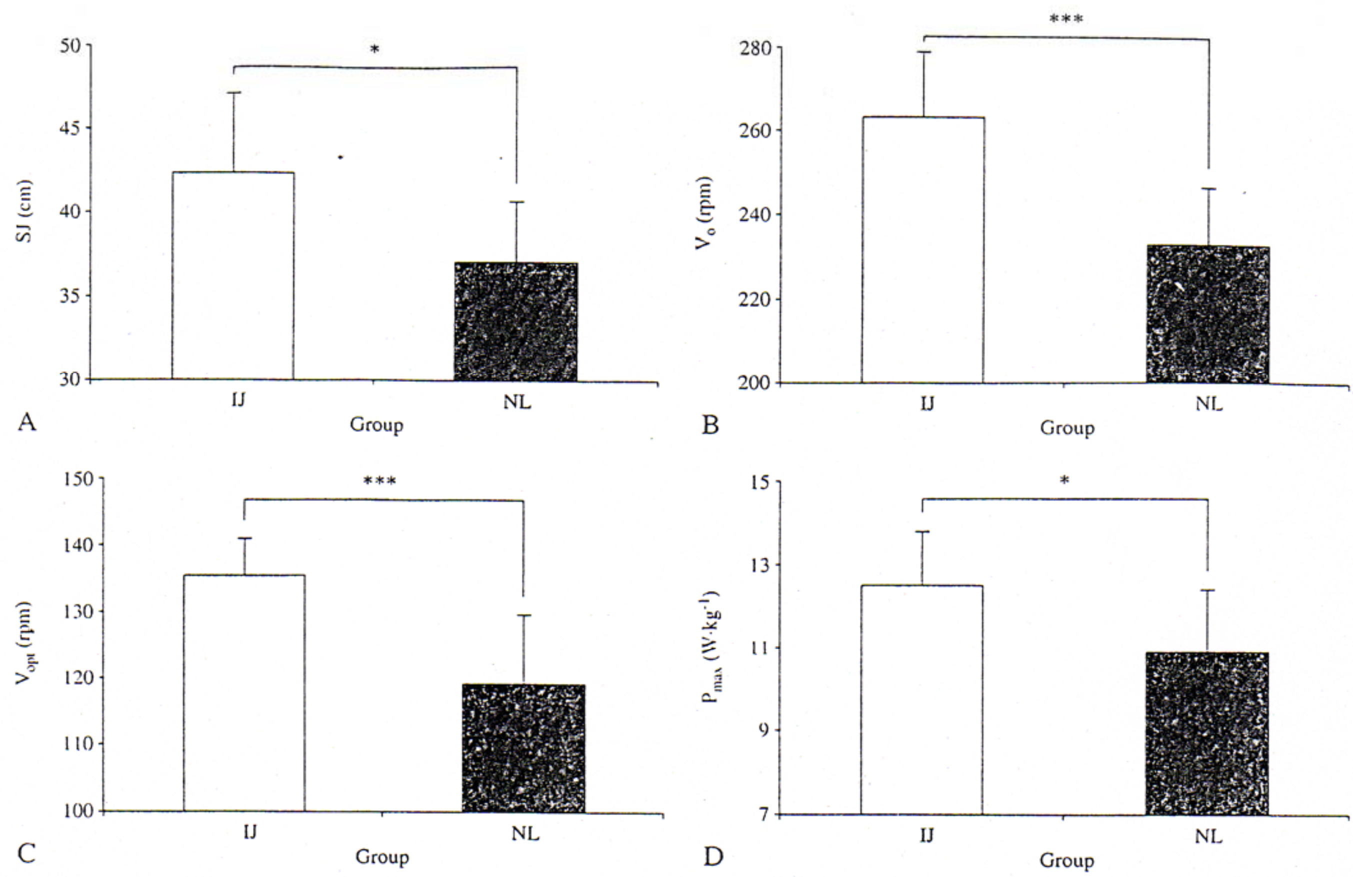

Figure 3.—Significant differences in mechanical variables between IJ and NL groups. The significant differences in SJ (A) in V_0 (B) in V_{opt} (C) and P_{max} (D) was specified using Mann-Withney test (* $p<0.05$, *** $p<0.001$).

TABLE III.—*Correlation matrix between results of the different tests.*

Variables	CMJ (cm)	V_0 (rpm)	V_{opt} (rpm)	F_0 (N·kg^{-1})	P_{max} (W·kg^{-1})
SJ (cm)	0.92 ***	0.51 *	0.49 *	0.12 NS	0.42 NS
CMJ (cm)		0.46 *	0.47 *	0.13 NS	0.40 NS
V_0 (rpm)			0.89 ***	0.16 NS	0.74 ***
V_{opt} (rpm)				0.43 *	0.85 ***
F_0 (N·kg^{-1})					0.77 ***

*:p<0.05, ***:p<0.001, NS: p>0.05

placement relies more on contraction velocity than muscle strength. However, it seems premature to conclude that karate performance is related to V_0, V_{opt}, P_{max} and SJ. Because of obvious difficulties with quantitative assessment of karate performance, it seems virtually impossible to classify karate practitioners and then to carry out correlation analyses of individual results. Further investigations would be necessary to state the suitability of tests proposed to predict performance potential in karate.

The V_0 values obtained for total and IJ groups were higher (+23.2 and +29.6 rpm, respectively) compared with results reported by Driss *et al.*[5] with volley ball players of district league. In addition, Vandewalle *et al.*[9] reported lower V_0 values for rugby (-18.7 rpm), tennis (-16.7 rpm), cycling road practitioners (-27.7 rpm) and sprint runners (-9.7 rpm) compared with the total group of this study. The average values of SJ observed for the total group (Table II) were in accordance with those reported by Bosco [6] with the Italian fencing national team and with the Finnish ice-skating national team. However they were greater (+7.7 cm) compared with the values previously reported by Hautier *et al.*[12] obtained on ergojump with sprint runners. These finding suggest that V_0, and SJ are valid and sensitive variables in order to reveal mechanical functional characteristics in karate competitor which could be particularly valuable when monitoring training. High values of V_0 and SJ observed in this study compared with the literature should support the hypothesis that maximal velocity and explosive strength are the major muscle mechanical factors involved in karate performance.

The P_{max} revealed significant differences between IJ and NL groups (Figure 3D). The P_{max} in IJ group was higher compared with values reported by Arsac [11] with long distance runners (9.6±1.3 W·kg^{-1}) and was in agreement with those reported by Hintzy *et al.*[14] with subjects practising explosive sports (12.6±1.9, W·kg^{-1}). P_{max} of the total group (11.6±1.6 W·kg^{-1}) was in accordance with the recent study of Morin *et al.*[7] that reported low Pmax values (11±1 W·kg^{-1}) in junior sprint runners. On the other hand, Pmax was lower in IJ group compared with values reported by Hautier *et al.*[12] with subjects trained for cycling sprints (P_{max} 14.4±2.4 W·kg^{-1}) and by Arsac [11] with sprint runners (P_{max} 16.1±1.6 W·kg^{-1}). Thus, it couldn't be assumed that Pmax is a major mechanical factor involved in karate performance.

Comparison between OB and DB subgroups

The OB subgroup was characterised by significantly higher CMJ (+15.1%) and SJ (+18.8%) compared with the DB subgroup. However, Δ_{CMJ-SJ} that accounts for the recoil of elastic energy and myoelectrical potentiation [15-17] presented no significant difference between groups. This result suggest that muscle elastic properties are similar. CMJ reveals differences only between OB and DB subgroups, whereas high SJ values characterised IJ and OB groups. Based upon variation coefficient, OB and DB subgroups were homogeneous for CMJ and SJ variables. These results suggest that CMJ and SJ (that analyse explosive strength) [6] could be proposed for relevant evidences of the attacking propensity.

Furthermore, no significant difference in V_0 was observed between OB and DB subgroups whereas V_0 was significantly higher in IJ group compared with NL group. This result confirm that this indirect evidence is particularly reliable to the skill level in karate.

Attacking propensity (offensive or defensive behaviour) could be a crucial element in the analyze of the mechanical muscle characteristics of karate practitioners.

Functional assessment and estimation of mechanical muscle properties

In this study P_{max} was significantly linked to F_0, V_0 and V_{opt}. The result of previous studies [5, 9] reported a relationship only between P_{max} and F_0. Indeed, Vandewalle *et al.*[9] reported that after training, the increase of the P_{max} was entirely due to the F_0 increase. Our results suggest that the increase of P_{max} in karate practitioners is due to the improvement of both force and velocity abilities. Moreover, this result is corroborated by the significant correlation observed between V_{opt} and P_{max} according to Arsac *et al.*[10] and Hintzy *et al.*[13-14] (*i.e.*, the higher V_{opt} the more P_{max} for the subjects). The V_{opt} and the P_{max} observed for the total group (Table II) were in agreement with previous data reported by the literature [10-12, 14] conducted in subjects practising explosive sports and V_{opt} (126.5±11.7 rpm) were higher than those measured in long distance runners (114±9 rpm).[11] In addition V_{opt} observed for the IJ group (135.4±5.6 rpm) were in accordance with those reported by Arsac [11] with sprinters (138±7 rpm). Force-velocity and power-velocity relationships generated on ergometer involving the lower limbs extensor muscles have been usually examined in the light of the mechanical characteristics of human type I and II muscle fibres.[24-28]

The content of the lower limb extensor muscles determined by biopsy has been related [29-31] with indirect evidences (V_{opt}, P_{max}, V_0 and SJ) from force-velocity and vertical jump tests. Hautier *et al.*[12] showed that both V_{opt} and SJ were positively related to the proportion of fast twitch fibres in the *vastus lateralis*.

Sargeant [29] suggested that type II fibres have a higher optimal velocity compared with type I fibres. Thus V_{opt} could particularly account for the relative contribution of types I and II fibres for the maximal power. Thorstenson *et al.*[31] have demonstrated that subjects with a higher percentage of fast twitch fibres had a higher maximal velocity than subjects with lower percentage. In agreement with these results, a positive relationship was obtained in this study between V_{opt} and V_0 for the total group as well as for IJ and NL groups and between SJ and V_{opt}, and between SJ and V_0 (for the total group), (Table III). Bosco *et al.* [24] and Hautier *et al.*[12] have reported that the higher the percentage of type II fibres was, the more the squat jumps were. However, based upon indirect evidences the interpretation of our data needed caution attitude and this point should deserved further investigation.

Conclusions

This study showed that force - velocity and squat jump tests may be applied in the functional assessment of karate competitor. Indirect evidences of velocity (V_0, V_{opt}) and explosive strength (*SJ*) seems valid and sensitive mechanical variables in order to reveal functional characteristics in karate competitor. *CMJ* test was particularly adjusted to account for attacking propensity. The explosive strength is a major mechanical characteristic involved in karate performance, specially for the assailant practitioners' behaviour.

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