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RELATIONSHIP BETWEEN FUNCTIONAL MOVEMENT SCREEN AND ATHLETIC AND KARATE PERFORMANCE IN ADOLESCENTS

original paper
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ABSTRACT
Purpose. The tests of athletic and functional performance are widely used to assess physical ability and set performance goals. The aim of this study was to evaluate the relationship between functional movement and physical and karate-specific performance in adolescents.
Methods. Karate technique, athletic performance, and Functional Movement Screen (FMS™) were evaluated in 20 karateka aged 10–15 years (age: 12.2 ± 1.9 years, height: 155.5 ± 16.5 cm, weight: 48.6 ± 19.5 kg). Correlation analysis determined the association between the various tests, and stepwise linear regression established performance prediction models.
Results. Only individual FMS™ tests of deep squat, hurdle step, and push-up significantly correlated with *gedan barai/jaku zuki* (r = 0.40, r = –0.61, r = –0.59, respectively) and the triangle step (deep squat: r = 0.43, push-up: r = –0.56). Muscular endurance, power, and agility showed a significant ($p < 0.05$) correlation with karate side-step and *gedan barai/jaku zuki*. The participants' body mass and muscle endurance were good predictors of *mawashi geri* ($r^2 = 0.51$, $p < 0.05$), while body mass was a strong indicator of *gedan barai/jaku zuki* ($r^2 = 0.46$, $p < 0.05$) and muscle endurance was a leading predictor of *gedan barai* ($r^2 = 0.34$, $p < 0.05$).
Conclusions. A combination of functional and athletic tests may be used to assess young athletes' predisposition to karate. The training focus in young karateka should be on developing fundamental movement capacity along with fundamental sport-specific skills to allow the young athlete's natural physical development.
Key words: martial arts, youth sports, strength training, functional screening

Introduction

Karate is one of the oldest and most popular forms of martial arts. It is considered an essential part of the physical education program for young children in most Asian countries. Previous research shows that participation in karate increases strength, speed, balance, posture, and coordination [1], and is therefore a recommended physical activity for young practitioners. Consequently, the popularity of youth participation in western countries is on the rise. However, as the popularity increases, the emphasis of youth participation is shifting from recreational enjoyment-driven activity to a structured sport-specific skill development with focus on excelling through different levels. In this regard, it is essential for children and adolescents to develop proficiency in fundamental movement skills as building blocks to specialized sport-specific skills required for level progression [2, 3]. In most sports, pre-participation screening methods have been widely used to identify these characteristics, in addition to setting performance goals and identifying young athletes potentially at risk of becoming injured [4]. Yet, to our knowledge, for martial arts and karate, there are limited data on reliable screening strategies that coaches may use in evaluating young karateka.

Generally, athletic performance and sport-specific skills in young athletes are highly related to the balance between chronological age and physical development [5–7]. Hence, exposing young athletes to re-

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petitive high-volume training without mastering the functional and fundamental movement skills may cause a change in movement patterns, alter motor control, and potentially lead to long-term physical impairment [5–8]. In martial arts, coordination and motor control required for the execution of technical elements lead to specific adaptations in explosive strength, flexibility, and agility that differ from those in other sports [3, 7, 9]. These differences are noted not only among sports [7], but also among martial arts disciplines, such as judo, karate, and taekwondo [9]. Therefore, identifying specific pre-participation screening tools is of great importance for coaches to be able to screen and identify young athletes with physical readiness and functional ability to perform karate-specific skill at the expected level [8].

Functional Movement Screen (FMS™) has become a widely used tool to identify fundamental movement limitations and assess movement quality, muscle strength, flexibility, range of motion, balance, and coordination [10]. With regard to martial arts, FMS™ has been found to identify movement dysfunctions in adult athletes [11]. As a subjective assessment of movement quality, it may also reveal muscular limitations and asymmetries, and correlate with physical fitness tests [4] in young martial artists participating in different sports [12] and in young soccer players [5]. Interestingly, children engaged in martial arts have reported higher total FMS™ scores [10] than their peers participating in general physical activity [13] or in specialized sports like soccer [5, 6].

Yet, despite these differences, there are limited data on using FMS™ to evaluate functional movement capacity in karateka. Furthermore, even with its widespread application, studies have reported equivocal results in FMS™ relationship to athletic performance [14], and the use in evaluating young athletes [6]. Therefore, in order to help coaches and trainers develop karate-specific screening tests that might be employed to identify physical and functional deficiencies in young karateka, the primary aim of this study was to determine if a relationship exists between FMS™, athletic performance, and karate-specific techniques in young athletes.

Material and methods

Overall, 20 karate athletes (age: 12.2 ± 1.9 years, height: 155.5 ± 16.5 cm, weight: 48.6 ± 19.5 kg) volunteered for the study. The participants had 7.5 ± 2.42 years of karate experience on average, with belt colour ranging from orange to brown. They were eligible for the study if they (1) were aged 10–15 years; (2) were free of any musculoskeletal injuries; (3) were able to complete all the required tests; (4) had at least 1 year of continuous karate practice; and (5) provided their assent and a written consent from their parents/guardians to participate in the study. All tests were performed across 3 different sessions: FMS™, athletic performance, and karate performance.

FMS™ constitutes a battery of 7 tests which were explained in detail by Cook [4]. Briefly, the participants were evaluated on the execution of a deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TSPU), and rotary stability (RS). Each test was scored on an ordinal scale of 1–3, in accordance with the standardized criteria set by Cook [4]. The functional screen assessment was performed by a qualified sports scientists with Level 2 FMS™ certification.

The following tests of athletic performance were selected from previous studies that identified their association with karate performance [15]; hence, only brief description of each test will be provided: 20-m (10-m) sprint as a standard assessment of speed and acceleration [14, 16]; agility *t*-test [14]; single-leg horizontal jump to assess leg power and bilateral functional asymmetry [17]; 1-minute sit-up and push-up tests [18]; standing toe reach flexibility [19]. The athletes performed 3 trials with a 5-minute rest interval for each test but were allowed to perform the next trial whenever ready within the certification of this period. All performance tests were implemented by a qualified sports scientist within strength and conditioning.

The selected tests of karate performance were also previously validated [3, 20, 21]; hence, only brief description will be provided. Side-step is a karate modification of the Edgren side-step test. The participants were asked to 'shuffle' 6 times the distance of 5 meters as fast as possible while holding the combat karate position, *fudo dachi* [3, 20, 21]. The triangle step is used to estimate specific movement speed by moving as fast as possible in a guard position along the sides of an equilateral triangle with 3-m long sides [3, 20]. The combination of a blockade and a blow, *gedan barai/jaku zuki*, is one of the fundamental combinations in karate, and the subjects were asked to perform this combination 5 times at a maximal speed while hitting a bag [3, 20]. Lastly, the athletes were assessed on the speed of a blocking technique, *gedan barai*, by performing a maximum number of blockades in 30 seconds [3, 20], as well as on the speed of a karate kick, *mawashi geri*, by performing as many kicks against a punch bag as possible in 30 seconds. The height of the kick was marked on the bag equivalent to the participant's neck height [3, 20]. The participants were to perform each kick from the same starting position, and had to at least touch the indicated line to be counted. The correct execution of the karate techniques was evaluated by a black belt karate instructor, and the best of 3 trials was used for analysis.

The statistical analysis was performed with SPSS version 23 (IBM, Armonk, USA). A two-tailed Pearson correlation analysis served to determine the association between the fitness tests, FMS™, and the karate-specific tests. A stepwise multiple regression analysis was used to establish the impact of performance variables on each karate performance variable. Bilateral differences were assessed with a dependent *t*-test. Statistical significance of the results was accepted at $p < 0.05$.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by Stellenbosch University Ethics Committee.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Table 1 presents the participants' performance data.

The FMS™ score for each test was presented in Figure 1, and the distribution for each test was as follows: DS: 1 – 10%, 2 – 80%, 3 – 10%; HS: 1 – 25%, 2 – 60%, 3 – 15%; ILL: 1 – 30%, 2 – 70%, 3 – 0%; SM: 1 – 0%, 2 – 45%, 3 – 55%; ASLR: 1 – 55%, 2 – 25%, 3 – 20%; TSPU: 1 – 55%, 2 – 15%, 3 – 30%; RS: 1 – 0%, 2 – 100%, 3 – 0%.

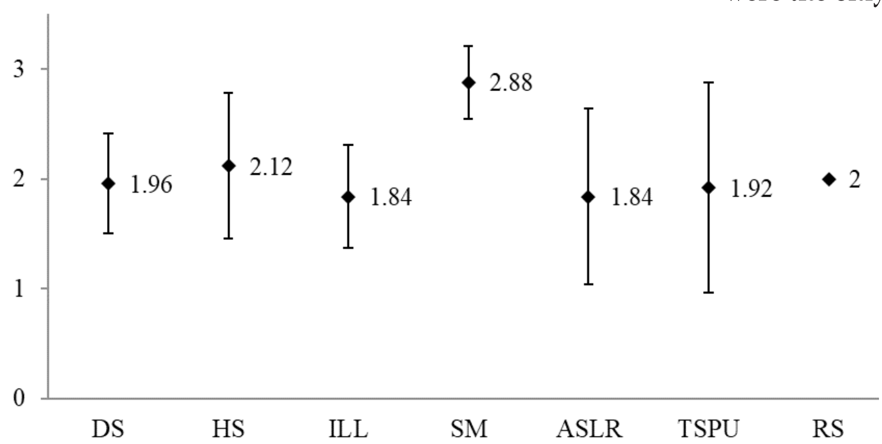
Table 1. Test results for all performance variables

Variable	Mean ± *SD*	95% CI
Sit-and-reach (cm)	–2.4 ± 8.1	–6.3 – 1.4
FMS™ score	13.5 ± 1.8	12.7 – 14.4
10-m sprint (s)	2.47 ± 0.23	2.36 – 2.58
20-m sprint (s)	4.16 ± 0.47	3.96 – 4.38
Agility *t*-test (s)	12.80 ± 1.10	12.28 – 13.32
Hop test (cm)	31.2 ± 7.1	27.9 – 34.5
Sit-up (*n*)	41.85 ± 8.36	37.9 – 45.8
Push-up (*n*)	17.20 ± 8.17	17.4 – 25.0
Side-step (s)	9.87 ± 1.24	9.29 – 10.45
Triangle step (s)	9.38 ± 0.91	9.78 – 8.98
Gedan barai/jaku zuki (s)	3.70 ± 0.55	3.44 – 3.96
Gedan barai (*n*)	27.80 ± 5.04	25.59 – 30.01
Mawashi geri (*n*)	20.10 ± 3.09	18.65 – 17.55

There were no bilateral differences in the functional screen, except for the ASLR test, where the right leg showed a significantly better range of motion ($p < 0.05$). A large variability was observed in individual FMS™ tests. The coefficient of variation equalled 49.7% for TSPU, 43.5% for ASLR, and 31.4% for HS. The SM test presented the lowest variability: 11.5%.

The inferential analysis (Table 2) shows that several FMS™ tests – DS, HS, and TSPU – demonstrated significant associations with specific components of karate performance. Interestingly, all participants scored the same at the RS test, which resulted in lack of association with other parameters.

The relationship between fitness and karate tests is presented in Table 3, which indicates that the fitness tests had a significant moderate-to-large association with karate performance. Yet, the stepwise linear regression revealed that weight was the only predictor for the *gedan barai/jaku zuki* performance (r = 0.68), explaining 46% of variance, while sit-ups were the only significant predictor of *gedan barai* (r =



DS – deep squat
HS – hurdle step
ILL – in-line lunge
SM – shoulder mobility
ASLR – active straight leg raise
TSPU – trunk stability push-up
RS – rotary stability

Figure 1. FMS™ mean scores and standard deviations

Table 2. Pearson correlation between karate performance and FMS™ tests

	Side-step	Triangle step	*Gedan barai/ jaku zuki*	*Gedan barai*	*Mawashi geri*
Deep squat	0.32	0.43*	0.40*	–0.39	–0.22
Hurdle step	–0.37	–0.29	–0.61**	0.58**	–0.23
In-line lunge	0.16	0.28	0.20	0.05	0.31
Shoulder mobility	–0.01	0.00	0.23	–0.11	0.16
Active straight leg raise	–0.07	–0.27	0.01	0.30	0.54*
Push-up	–0.50*	–0.56*	–0.59**	0.22	–0.22
Rotary stability	–	–	–	–	–

Significance at: * $p < 0.05$, ** $p < 0.01$

Table 3. Pearson correlation between karate performance and athletic screen

	Side-step	Triangle step	*Gedan barai/ jaku zuki*	*Gedan barai*	*Mawashi geri*
Flexibility	–0.08	–0.01	0.11	–0.58**	–0.52*
Sit-up	–0.69**	–0.41^{x}	–0.57**	0.58**	0.06
Push-up	–0.55*	–0.16	–0.44*	0.31	0.03
10-m sprint	0.49*	0.11	0.05	–0.22	–0.27
20-m sprint	0.75**	0.32	0.46*	–0.35	0.10
Agility *t*-test	0.73**	0.24	0.50*	–0.55*	–0.03
Hop test	–0.62**	–0.24	–0.61**	0.52*	–0.40^{x}

Significance at: * $p < 0.05$, ** $p < 0.01$, ^{x} $p = 0.07$

0.58), accounting for 34% of variance. Consequently, variance in *mawashi geri* was predictable by 2 models: weight ($r = 0.62$, $r^2 = 0.38$) and weight and sit-ups ($r = 0.72$, $r^2 = 0.51$), with 13% improvement in the second model. It is noteworthy that there were bilateral differences in the hop test: the participants jumped significantly longer with their dominant (right) than with the non-dominant leg ($p < 0.05$).

Discussion

The primary findings of this study indicate that the total FMS™ score had no significant relationship with karate-specific or fitness tests in our participants. However, the individual tests focusing on core strength and control, hip mobility, and flexibility (TSPU, HS, and ASLR, respectively) were strongly associated with karate performance and may be suitable for screening motor control in young karateka. In addition, push-up and sit up fitness tests seem to be significant predictors of karate-specific performance in young athletes. Given that the results of our study were comparable with previous research investigating FMS™ [5, 8], fitness tests [22, 23], and karate scores [20] in similar populations, these findings may be used for designing karate-specific assessment strategies for young karateka.

Firstly, the TSPU test score corresponded strongly with the faster times at the 2 karate agility tests: the side-step test ($r = –0.50$, $p = 0.026$) and the triangle step test ($r = –0.56$, $p = 0.011$). As the name designates, the TSPU test is an indicator of isometric core strength and trunk stability and control during movement. Therefore, as both karate agility tests were performed in the combat karate stance *fudo dachi*, which requires trunk stability during the execution of various karate forms, there is a strong association between functional and strength requirements for both types of tests.

Similarly, the *gedan barai/jaku zuki* (block/blow) combination was strongly associated with the TSPU and the hurdle step tests, which also assess the stability between the pelvis and the trunk during movement. In both tests, participants must demonstrate bilateral and asymmetric hip mobility and trunk stability. More specifically, during the *gedan barai/jaku zuki* combination, karateka start and finish the combination in the *zakutsu dachi* position (front stance), while maintaining a straight and stable posture. The mobility and stability needed to transition between subsequent front stance positions enables karateka to avoid the opponent's attack [20]. Similarly, during the HS test, the stance leg provides stability, while the forward leg (hip) has do demonstrate adequate mobility to step over the hurdle. At the same time, karateka must maintain stable and erect trunk position in order to assume the optimal position for the follow-up block/blow combination. Equally during HS, participants must maintain stable and erect posture, demonstrating trunk stability. Both of these components are further tested by adding the speed component. Trunk stability during *gedan barai/jaku zuki* allows for an effective transfer of angular momentum at the beginning and at the completion of the block or a punch. In this regard, abdominal strength is required to maintain trunk stability during step-to-step transition, and preparation and execution of the block/blow combination. Consequently, the correct execution of this technique has been found to be the best predictor of fighting efficiency in young karateka [20]. These tests demonstrate the significance of core stability in the technical elements of karate.

Lastly, the successful execution of the high kick *mawashi geri* as tested in this study requires a high level of general motor efficiency, determined primarily by hamstring flexibility and subsequently by the range of motion and stability of the pelvis, but also by speed and subsequent motor control during movement. The results show a strong correlation of *mawashi geri* with the ASLR test, which assesses lumbar and pelvic stability and hamstring flexibility (p = 0.014), as well as a strong potential relationship with the hop test, assessing leg power (p = 0.07). These results indicate that both ASLR and hop tests may be useful and practical tests in young karateka screening. However, coaches should apply caution in designing tests that require power and motor coordination when fundamental movements are not well developed. For example, the ASLR and ILL tests were the lowest scoring ones in the FMS^{TM}, which potentially indicates lack of hip and ankle mobility and stability, limited quadriceps flexibility, and potential knee instability. It is therefore recommended that the cause of this low score is immediately identified and corrected if possible in order to prevent potential injuries [4].

With regard to athletic performance, the tests in this study evaluated upper and lower body strength and acceleration (i.e. power) and were strongly associated with karate performance, which is indicative of the importance of explosive power for young karateka [20, 24]. Interestingly, this relationship was co-dependent on age and anthropometric characteristics of the participants, which was not the case in the FMS^{TM} screen. When accounting for age, the side-step and *gedan barai/jaku zuki* combination remained strongly associated only with the agility *t*-test. As discussed earlier, agility enables the karateka to avoid the opponent's attacks and to assume an optimal position for subsequent manoeuvres. Combining agility testing with karate-specific technique combinations may be a strong indicator of fighting efficiency [20]. Hence, designing specific agility tests by incorporating karate-specific skills may be a plausible alternative to traditional agility tests for karateka screening.

Further analyses of athletic performance via stepwise linear regression showed that weight might explain 46% of the variation in *gedan barai/jaku zuki* and 38% of variance of *mawashi geri*. Given that weight is directly related to the age of participants (r = 0.87, $p \leq 0.001$), these results further point to the association between strength and development age of children. Hence, our research supports the recommendation that children in the first 2 stages of sports development (6–14 years) focus on general physical development, as basis for further development of specific motor abilities that lead to transition to specialization [2, 3, 9, 20].

Conclusions

When designing a screening process for beginner and young karateka, coaches and trainers should use both functional and physical performance tests to devise a comprehensive assessment strategy. More specifically, while the total FMS^{TM} score may not be useful as an indicator of athletic or karate performance, the individual tests designed to asses specific functional limitations, such as ASLR, TSPU, and HS, may provide valuable information about the athlete's functional capacity. General tests of athletic performance for agility and power may also be useful tools for evaluating karate efficiency in young karateka. While both technique and physical characteristics of young athletes are strong indicators of karate performance, emphasis should continue to be placed on developing a correct fundamental movement technique in young athletes, as it is less dependent on age.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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