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Effects of simulated *kata* competition on upper- and lower-body power tests performance

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Abstract

Thirty male senior *kata* athletes representing the karate styles *Shotokan* (*n*=10), *Gojuryu* (*n*=10) and *Shitoryu* (*n*=10), were recruited to verify their neuromuscular response to a simulated competition comprised of five different successive *kata*. They executed the medicine ball throw test and the countermovement jump test in two days, a control and a *kata* condition. For the upper-body muscle power, there was an effect of moment ($F_{9,486}$ = 3.55, *p* < 0001, η_p^2 = 0.062, medium) with higher values pre 1 compared to pre 5 (*p* < 0.001; *d* = 0.31, small). For the lower-body muscle power, there was a moment and condition interaction effect, with higher values pre *kata* 1 compared to pre *kata* 3 (*p* = 0.002; *d* = 0.34, small) and pre *kata* 5 (*p* < 0.001; *d* = 0.41, small). Conversely, higher values post *kata* 5 compared to pre *kata* 5 (*p* < 0.001; *d* = 0.31, small). There was no interaction among moment, style and condition. The *kata* simulated competition did not affected the upper-body power performance but the athletes started the third and fifth *kata* executions with reduced lower-body muscle power. Conversely there was an improvement in legs muscle power after *kata* 5 comparing to the pre *kata* 5. These results provide important information about the category and how the athletes are affected during a simulated competition.

Keywords: Combat sports; martial arts; karate; muscle power; countermovement jump; medicine ball throw.

Efectos de la competición de kata simulada en el rendimiento en test de potencia de la parte superior e inferior del cuerpo

Resumen

Treinta atletas masculinos que representan los estilos de karate *Shotokan* (n = 10), *Gojuryu* (n = 10), y *Shitoryu* (n = 10), fueron reclutados para verificar las respuestas neuromusculares durante una competencia simulada que consta de cinco *kata* múltiples. Realizaron las pruebas de rendimiento test de lanzamiento de balón medicinal y test de salto con contramovimiento em condiciones de control y *kata*. Para el desempeño de los miembros superiores, hubo un efecto momentáneo ($F_{9.486}$ = 3.55, P < 0001, η_p^2 = 0.062, media) con valores más altos pre 1 en comparación con pre 5 (p < 0.001; d = 0, 31, pequeño). En cuanto al desempeño de miembros inferiores, hubo efecto de interacción entre momento y condición, con valores más altos pre *kata* 1 en relación a pre *kata* 3 (p = 0,002; d = 0,34, pequeño) y pre *kata* 5 (p < 0,001; d = 0,41, pequeño). Por otro lado, valores más altos después de *kata* 5 en comparación con pre *kata* 5 (p < 0,001; d = 0,31, pequeño). No hubo interacción entre el momento, el estilo y la condición. La competencia de kata simulada no afectó el rendimiento de los miembros superiores, pero los atletas comenzaron el tercer y quinto *kata* con un rendimiento reducido de los miembros inferiores. Por el contrario, hubo una mejora en el rendimiento después del *kata* 5 en comparación con el pre kata 5 en relación con las

Efeitos da competição simulada de *kata* no desempenho dos testes de força da parte superior e inferior do corpo

Resumo

Trinta atletas masculinos representando os estilos de caratê *Shotokan* (n = 10), *Gojuryu* (n = 10) e *Shitoryu* (n = 10) foram recrutados para verificar as respostas neuromusculares durante competição simulada composta por cinco múltiplos *kata*. Eles executaram os testes de desempenho arremesso de bola medicinal e salto com contramovimento em condição controle e condição *kata*. Para o desempenho de membros superiores houve um efeito de momento ($F_{9,486}$ = 3,55, P < 0001, η_p^2 = 0,062, médio) com valores mais elevados pré 1 comparado com pré 5 (p < 0,001; d = 0,31, pequeno). Em relação ao desempenho de membros inferiores, houve um efeito de interação momento e condição, com valores mais elevados pré *kata* 1 em relação ao pré *kata* 3 (p = 0,002; d = 0,34, pequeno) e pré *kata* 5 (p < 0,001; d = 0,41, pequeno). Por outro lado, valores mais elevados após *kata* 5 em comparação com pré *kata* 5 (p < 0,001; d = 0,31, pequeno). Não houve interação entre momento, estilo e condição. A competição simulada de *kata* não afetou o desempenho de membros superiores, mas os atletas iniciavam o terceiro e quinto *kata* com desempenho reduzido de membros inferiores. Contrariamente, houve uma melhora de desempenho após o *kata* 5 comparado com o pré *kata* 5 em relação aos membros inferiores.

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extremidades inferiores. Estos resultados proporcionan información importante sobre la categoría y cómo se ven afectados los atletas durante una competición simulada.

Palabras clave: Deportes de combate; artes marciales; Karate; potencia muscular; salto con contramovimiento; lanzamiento de balón medicinal.

Esses resultados fornecem informações importantes sobre a categoria e como os atletas são afetados durante uma competição simulada.

Palavras-chave: Desportos de combate; artes marciais; caratê, potência muscular, salto com contramovimento, arremesso de bola medicinal.

1. Introduction

Karate was developed and organized as a martial art training methodology on the XX century by Gichin Funakoshi (Arriaza, 2009). World Union Karate Organization (WUKO) held its first world tournament in 1972 on the target of spreading the practice worldwide including two different competitive disciplines called *kata* and *kumite.* Later on, WUKO changed to World Karate Federation (WKF) which is nowadays the official karate organization and will debut both categories at the Tokyo Olympic Games (World Karate Federation, 2020).

Different karate styles were established by the *Dai Nippon Butoku Kai* in the early 1930s because there were many technical differences among the karate teachers who came from Okinawa. This Japanese organization, responsible to promote and standardize martial arts, recognized the *Shotokan, Gojuryu, Shitoryu* and *Wadoryu* styles, which are still considered official styles by the WKF (Cramer, 2018).

The structure of a *kata* competition is composed of multiple *kata* performances from an official list (102 *kata*) among the four styles recognized by WKF. It has exclusively male or female divisions. Depending on the number of competitors enrolled there will be a specific number of *kata* to be performed; when there are between 25 to 96 competitors, athletes need to execute 4 different *kata* and above 97 athletes, they have to perform 5 *kata* (World Karate Federation, 2020).There is no style division in the most important *kata* tournaments so the athletes from different styles compete among them. Basically, the competitors are divided in groups of 8 and the four best ranked in each group pass on to the next round and then the groups are rearranged to perform another *kata.* When there are only two remaining groups, the highest scoring athlete for each group will compete for the first and second places and the athlete number two will dispute with the athlete number three from the other group for the third place. Each performance receives an evaluation score composed by 70% technical criteria and 30% athletic criteria by a minimum five and a maximum of seven referees. The technical judgement includes stances, techniques, transitional movements, timing, correct breathing, conformance with the style and *kime,* which represents a short isometric contraction at the end of each strike (Doria et al., 2009) and the athletic criteria includes strength, speed and balance (World Karate Federation, 2020).

Because *kata* was formulated as a fighting system (Francescato, Talon & Di Prampero, 1995) athletes execute several lower- and upper-body high-intensity actions, which are likely to demand high levels of muscle power interspersed by smooth low-intensity gestures and body displacements. The usual *kata* chosen at competitions last between 90 s to 180 s (Augustovicova, Stefanovsky, Argajova, & Kampmiller, 2019). According to Francescato, Talon and Di Prampero (1995) 80 s of *kata* practice reached a metabolic power of 1.8 times the $\dot{V}O_{2max}$ and longer *kata* (140 to 160 s) reached values slighthly below 1.0 times the $\dot{V}O_{2max}$ (Doria et al., 2009). Regarding *kata* duration the energy system contribution is affected (Chaabène et al., 2015). The phosphagenic system (ATP-PCr) is the main responsible for intense and short *kata* (Francescato, Talon & Di Prampero, 1995; Bussweiler & Hartmann, 2012) and longer competitive *kata* (140 s to 160 s) keep approximately 30% the ATP-PCr system contribution (Doria et al., 2009).

Analysing the demands of one single competitive *kata* (Invernizzi, Longo & Scurati, 2008; Doria et al., 2009) is relevant to understand the real effort without any possible accumulated fatigue due to the successive *kata* execution, but it is also important to think that the competition is composed by multiple *kata* performances interspersed by intervals when the athletes wait for the results to progressing to the final bouts. Assessing neuromuscular responses in a simulated effort-pause structure similar to competitions would provide information about how the athletes cope with *kata* demands in a more ecological study design.

In combat sports, understanding responses through physical tests pre and post matches during simulated competitions composed by multiple bouts is a common practice because during either an official or simulated competition it is difficult to assess real time performance changes. Therefore, pre and post physical tests would provide information about the impact of the competitive stimulus on physical abilities relevant to competitive performance. Indeed, this approach has been used in several combat sports: in judo, maximal isometric strength (Bonitch-Góngora, Bonitch-Domínguez, Padial, & Feriche, 2012; Julio et al., 2018), countermovement jump and dynamic strength endurance (Julio et al., 2018); in Brazilian jiujitsu, maximal isometric strength, isometric strength endurance, sit and reach test and countermovement jump (Andreato et al., 2015); in wrestling, bear hug test, vertical jump, grip strength, hip and back strength (Kraemer et al., 2001; Barbas et al., 2011) and isokinetic strength (Kraemer et al., 2001); in taekwondo, countermovement jump (Chiodo et al., 2011; Detanico, Librizzi, & Athayde, 2016) and handgrip test (Chiodo et al., 2011). However, in karate only one study using this approach was found. Specifically, the assessment of vertical jump and the lower- and upper-body propulsive power were tested pre and post one single *kumite* match in a highly-trained double World champion athlete and the result was an increase in the height of the countermovement jump after the combat (Loturco et al., 2017).

Although some studies have been recently conducted to better understand the competitive *kata* category (Vujkov et al., 2015; Penov, Petrov & Kolimechkov, 2020) no study was found investigating the physical responses during simulated competition. Considering that athletes execute several lower- and upper-body high-intensity actions during each presentation and perform multiple *kata* along the competition, the proper recovery of muscle power is considered paramount to the athlete's success. Assessing upper and lower body power through physical tests in a simulated competition would provide information about how the athletes deal with the successive physical demands imposed on them and this knowledge about the category would be useful for training planning and to an improved preparation during the contest.

Therefore, the purpose of this study was to verify the responses of upper and lower muscle power physical tests applied pre and post multiple (i.e., 5) competitive *kata* and to compare these results in different styles (i.e., *Shotokan, Gojuryu* and *Shitoryu*) that participate into the same category. The main hypothesis of the present study was that there would be a decrease in the performance measures after each *kata,* but the pauses between them would be long enough for a full recovery of lower- and upper-body muscle power. Additionally, there would be no significant differences among the three styles concerning the muscle power responses along the simulated competition.

2. Materials and methods

2.1. Participants

Thirty male *kata* karate athletes (24 ± 6 years, 74 ± 11 kg, 173 ± 5 cm; 13 ± 7 years of practice) equally divided in three groups representing *Shotokan* (n = 10), *Gojuryu* (n = 10) and *Shitoryu* (n = 10) styles participated in this study; *Wadoryu* was not included because there are no representative *kata* athletes from this style at WKF tournaments. They were all brown or black belts and have been participating in previous and or current official competitions organized by the São Paulo State Karate Federation. Athletes took part voluntarily in the study after being informed about the procedures, risks and benefits. They also have signed an informed-consent form. All procedures were approved by the local ethics committee.

2.2. Measurements

Lower-body power was assessed by countermovement jump test (Komi & Bosco, 1978). Athletes were instructed to remain standing on a jump platform (Cefise, software Jump System 1.0.4.2, Nova Odessa, Brazil) with shoulders width feet apart and hands on the hips and perform a downward movement followed by complete knee extension and jump. Three maximal countermovement jumps with a 1-min pause between them were done. The highest jump value (cm) was utilized for analysis. Upper-body power was assessed via the medicine ball throw test (Johnson & Nelson, 1969). The test was performed using a 3-kg medicine ball (Carci, Brazil). Athletes in sitting position threw the ball from the chest with both hands. They were instructed that it was not allowed any kind of trunk or foot movement. Athletes executed three throws with a 1 min pause between them. The longest distance (cm) was utilized for analysis. The lower- and upper-body power tests were executed successively, i.e., during the 1-min interval of one test the other test was performed and vice-versa.

2.2. Design

All athletes were randomly evaluated in two, a control condition and a *kata* condition, separated by at least 48 hours and a maximum of 168 hours, and at the same time of day (Figure 1). Previously there was a familiarization session, when the athletes executed each of the tests that would be executed in each condition. In the control condition the athletes executed the physical tests (for both lower- and upper-body regions) interspersed by recovery pauses representing the five different *kata* durations. In the *kata* condition the athletes performed the same neuromuscular tests interspersed by each of the five different kata executions. At the beginning of both sessions there was a standard 9 min warm-up divided into 3 min of running, 3 min of general stretching and 3 min of *kata* movements. The athletes were advised to self-select the warm-up intensity according to their own experience simulating a competition, but in the allotted time proposed. A 3 min recovery pause was done before lower- and upper-body power tests. As soon as the warm-up finished the athletes were told which condition they would execute.

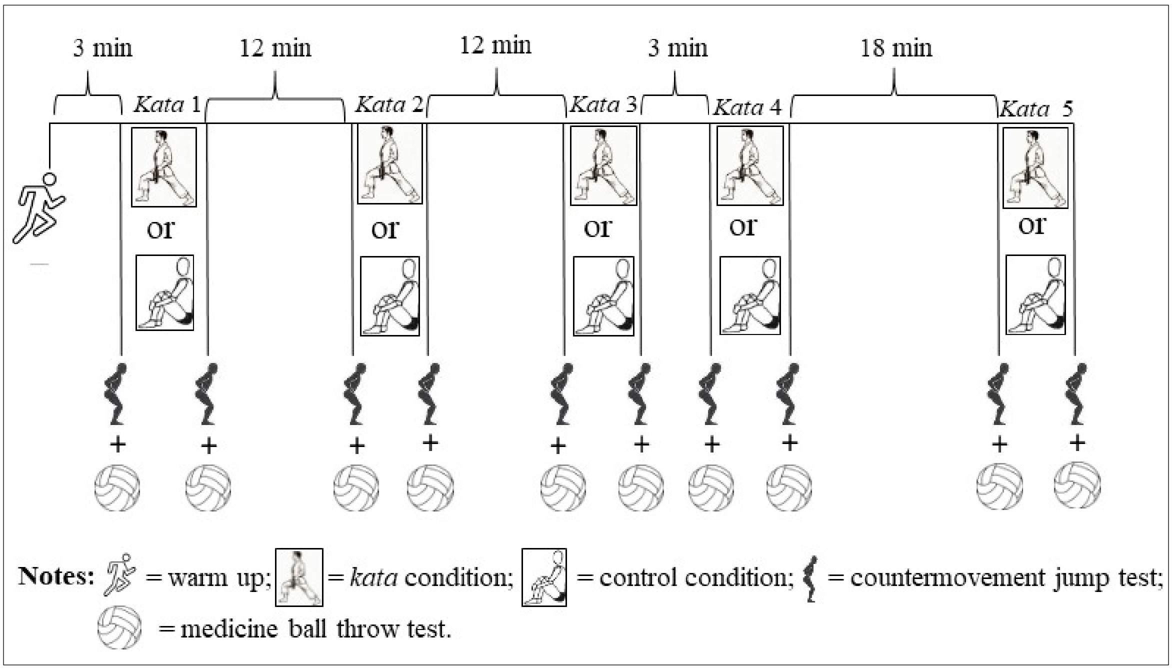

Figure 1. Study design.

Kata condition

The athletes from each style performed pre and post physical tests interspersed by five different *kata*. The sequence of the *kata* multiple condition was pre tests, *kata* execution, post tests and recovery pauses. These recovery pauses lasted 12 min, 12 min, 3 min and 18 min, and were based on the pauses between rounds of the male *kata* senior category at the senior São Paulo State Tournament disputed in 2017. The fifteen different *kata* were chosen according to the opinion of one black belt specialist of each style with more than 20 years of practice and they were among the most executed *kata* in recent tournaments (Augustovicova, Stefanovsky, Argajova, & Kampmiller, 2019). *Shotokan* style athletes performed the *Gojushiho sho, Gojushiho dai, Kankusho, Unsu* and *Gankaku, Shitoryu* style athletes performed the *Paiku, Chatanyara Kushanku, Kosokunsho, Anan* and *Nipaipo, whereas the Gojuryu* style athletes performed the *Suparimpei, Kururunfa, Seisan, Shisochin* and *Sanseru.* Table 1 shows a general *kata* description, including style, duration and the amount of arm techniques, leg stances or transitions, kicks and jumps. The data described in Table 1 were obtained by the analysis of one athlete of the sample from each style and the information was also checked by one specialist coach (*sensei*) from the respective style. This description can be slightly different depending on the interpretation of the coach (*sensei*), with no prejudice to the athlete's performance (World Karate Federation, 2020).

Control Condition

The athletes from each style performed pre and post physical tests interspersed by five different pauses representing the same *kata* duration (control). The sequence of the control condition was pre tests, recovery representing the *kata* duration, post tests and recovery pauses. As in the *kata* condition, these recovery pauses lasted 12 min, 12 min, 3 min and 18 min, and were based on the pauses between rounds of the male *kata* senior category at the senior São Paulo State Tournament held in 2017.

Table 1. *Kata* general description with style, duration (s) and number (n) of arm and leg techniques, and jumps.

Kata	Duration (s)	Arm techniques (n)	Stances/leg transitions (n)	Kicks (n)	Jumps (n)
Shotokan					
Gojushihosho	140	58	38	3	0
Gojushihodai	150	59	38	3	0
Kankusho	90	47	27	5	2
Unsu	100	44	26	5	1
Gankaku	120	42	25	6	1
Shitoryu					
Paiku	100	54	30	5	0
Chatanyara	140	60	50	8	2
Kosokunsho	90	48	40	5	1
Anan	110	41	28	9	0
Nipaipo	90	51	38	4	0
Gojuryu					
Sanseru	90	37	18	8	0
Suparimpei	180	91	44	3	1
Kururunfa	100	37	29	4	0
Seisan	100	44	17	5	0
Shisochin	90	50	28	2	0

2.3. Statistical analysis

Data are presented as mean and standard deviation. Comparison of the dependent variables was performed with a 3-way analysis of variance (style - 3 levels, condition - 2 levels and moment – 10 levels) with repeated measurements in the last two factors. When a significant F value was obtained ($p < 0.05$), a Bonferroni post hoc test was performed. Partial eta squared (η_p^2) was used as effect size and classified according to Cohen (1969): < 0.2 - small; 0.2 to < 0.8 - moderate; > 0.8 - large. Effect sizes for multiple paired comparisons were reported when a significant difference was found and it was calculated using Cohen *d* (Cohen, 1969) and classified according to Hopkins (2002): < 0.2 – trivial; > 0.2 to < 0.6 – small; > 0.6 to < 1.2 – moderate; > 1.2 to < 2.0 – large; > 2.00 to < 4.0 – very large; > 4.0 – nearly perfect.

Due to large quantity of data, post-hoc comparisons were presented considering differences between: 1) moment (Pre1, Pre2, Pre3, Pre4, Pre5, Post1, Post2, Post3, Post4, Post5) or style (*Shotokan*, *Gojuryu*, *Shitoryu*) or condition (*kata* or control), 2) interaction between style and condition - same style and different conditions or between different styles and same condition, 3) interaction between moment and condition - same moment and different conditions or different moments and same condition considering comparisons between pre to pre, post to post, or pre to post at the same *kata*, 4) interaction between style and moment – same style and different moments considering comparisons between pre to pre, post to post, or pre to post at the same *kata*, 5) interaction among style, condition and moment - same style and condition compared to different moments considering comparisons between pre to pre, post to post, or pre to post at the same *kata*; same style and moment considering different conditions; same condition and moment considering different styles.

3. Results

Table 2 shows the performance in the medicine ball throw test in different conditions and moments including athletes from three karate styles (*Shotokan*, *Shitoryu* and *Gojuryu*). For medicine ball throw, a main effect of moment was found ($F_{9,486}$ = 3.55, p < 0.001, η_p^2 = 0.06, small), with a decrease pre 5 compared to pre 1 (p < 0.001; d = 0.31, small). There were no effect for style ($F_{2,54}$ = 2.88, p = 0.065, η_p^2 = 0.09, small) and condition ($F_{1,54}$ = 2.30, p = 0.136, η_p^2 = 0.04, small) neither the following interactions: style and condition ($F_{2,54}$ = 0.63, p = 0.539, η_p^2 = 0.02, small); moment and style ($F_{18,486}$ = 1.38, p = 0.138, η_p^2 = 0.05, small); moment and condition ($F_{9,486}$ = 1.38, p = 0.192, η_p^2 = 0.03, small) and moment, style and condition ($F_{18,486}$ = 1.06, p = 0.387, η_p^2 = 0.04, small).

Table 3 shows the performance in the CMJ test in the different conditions and moments including the three karate styles (*Shotokan*, *Shitoryu* and *Gojuryu*). For the countermovement jump, a main effect of moment was found ($F_{9,486}$ = 13.59, p < 0.001, η_p^2 = 0.20, small), with a decrease pre 2 (p < 0.001; d = 0.28, small), pre 3 (p < 0.001; d = 0.43, small), pre 4 (p = 0.011; d = 0.20, trivial) and pre 5 (p < 0.001; d = 0.38, small) compared to pre 1, a decrease post 3 compared to post 1 (p = 0.025; d = 0.16, trivial), and a decrease pre 5 compared to pre 4 (p = 0.048; d = 0.17, trivial). Conversely, there were an increase post 3 compared to pre 3 (p = 0.022; d = 0.19, trivial), an increase pre 4 compared to pre 3 (p < 0.001; d = 0.23, small), and an increase post 5 compared to post 3 (p = 0.040; d = 0.16, trivial) and pre 5 (p < 0.001; d = 0.31, small).

There was also a moment and condition interaction ($F_{9,486}$ =3.05, p = 0.001, η_p^2 = 0.05, small). In the control condition, there was a decrease pre 2 (p = 0.013; d = 0.27, small), pre 3 (p < 0.001; d = 0.49, small), pre 4 (p = 0.039; d = 0.26, small), and pre 5 (p < 0.001; d = 0.42, small) compared to pre 1 and a decrease post 3 compared to post 1 (p = 0.008; d = 0.28, small). For the *kata* condition, there was a decrease pre 3 compared to pre 1 (p = 0.002; d = 0.34, small) and pre 5 (p = 0.023; d = 0.31, small). Conversely, there was an increase post 5 compared to pre 5 (p < 0.001; d = 0.41, small). There were no main effects for style ($F_{2,54}$ = 0.56, p = 0.577, η_p^2 = 0.02, small) and condition ($F_{1,54}$ = 0.46, p = 0.501, η_p^2 = 0.01, small), neither the following interactions: style and condition ($F_{2,54}$ = 0.24, p = 0.785, η_p^2 = 0.01, small), moment and style ($F_{18,486}$ = 0.88, p = 0.604, η_p^2 = 0.03, small), and moment, style and condition ($F_{18,486}$ = 0.91, p = 0.562, η_p^2 = 0.03, small).

4. Discussion

The main hypothesis of the present study was not confirmed because there was no decrease in performance measures after each *kata.* Regarding the duration of the recovery periods, they were long enough for maintenance of the lower- and-upper body performance, but when the recovery period was longer a loss in lower-body power assessment test was observed. Although all statistical significant results were reported, the discussion section will focus exclusively on the results obtained at *kata* condition due to the fact that in this study, the control condition was carefully designed to isolate the effects of the power tests applied along the *kata* simulated condition. Concerning lower-body muscle power performance, lower values were found pre *kata* 3 and pre *kata* 5 compared to pre *kata* 1, whereas improved performance after the *kata* 5 compared to pre *kata* 5 was observed. There was no difference between the styles *Shotokan, Gojuryu and Shitoryu* for both lower- and-upper muscle power results.

Regarding the lower-body muscle power performance, the athletes of three styles started the *kata* 3 and 5 with decreased performance compared to pre *kata* 1. The higher values in pre *kata* 1 could be related to the warm-up benefits while a decreased performance in pre *kata* 3 and pre *kata* 5 was a consequence of the loss of these benefits. According to Bishop (2003b), active warm-up improves short-term performances (lasting less than 10s) like the countermovement jump (4.2-7.8%) due to an increase in muscle temperature. This author recommends a warm-up structure that lasts between 5 to 10 min, at 40-60% $\dot{V}O_{2max}$ and a 5 min recovery pause between the warm- up and the task, which is likely to result in performance improvement on short-duration subsequent activities. Similarly recommended by Bishop (2003b), the warm-up of this study was divided into 3 min of aerobics, 3 min of general stretching and 3 min of *kata* movements totaling 9 min followed by 3 min recovery pause.

Table 2. Medicine ball throw test performance in different moments (10), styles (3) and conditions (2) during simulated kata competition (values are mean ± standard deviation; n = 30; 10 Shotokan, 10 Shitoryu, 10 Gojuryu athletes).

	Kata 1		***Kata 2***		***Kata 3***		***Kata 4***		***Kata 5***	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Control condition (m)										
Shotokan	3.88±0.64	3.90±0.58	3.76±0.58	3.77±0.48	3.75±0.49	3.72±0.46	3.80±0.48	3.67±0.46	3.75±0.46	3.77±0.46
Gojuryu	3.69±0.31	3.64±0.32	3.60±0.30	3.53±0.22	3.56±0.20	3.61±0.28	3.62±0.33	3.61±0.34	3.51±0.34	3.53±0.23
Shitoryu	3.77±0.31	3.76±0.33	3.71±0.43	3.70±0.36	3.73±0.39	3.77±0.42	3.78±0.40	3.75±0.39	3.71±0.37	3.81±0.51
Total	**3.78±0.44**	**3.77±0.42**	**3.69±0.44**	**3.67±0.37**	**3.68±0.38**	**3.70±0.39**	**3.74±0.40**	**3.68±0.39**	**3.66±0.40**	**3.70±0.42**
***Kata* condition (m)**										
Shotokan	4.17±0.80	4.26±0.83	4.16±0.81	4.20±0.81	4.06±0.77	4.07±0.77	4.11±0.82	4.13±0.80	3.96±0.65	4.18±0.77
Gojuryu	3.67±0.33	3.57±0.22	3.70±0.34	3.69±0.30	3.60±0.24	3.60±0.20	3.59±0.23	3.71±0.20	3.60±0.29	3.73±0.29
Shitoryu	4.02±0.44	3.93±0.48	3.66±0.47	3.81±0.35	3.85±0.43	3.73±0.43	3.92±0.38	4.03±0.35	3.79±0.35	3.91±0.51
Total	**3.95±0.58**	**3.92±0.62**	**3.84±0.60**	**3.90±0.57**	**3.84±0.54**	**3.80±0.54**	**3.87±0.56**	**3.96±0.53**	**3.78±0.47**	**3.94±0.57**
Control + *kata* conditions (m)										
Total	**3.87±0.52**	**3.84±0.53**	**3.76±0.53**	**3.78±0.49**	**3.76±0.47**	**3.75±0.47**	**3.80±0.49**	**3.82±0.48**	**3.72±0.43[a]**	**3.82±0.51**

Notes: [a] effect of moment: decline from pre 1 (p<0.001); control + *kata* condition (m) = mean ± standard deviation values obtained in control and *kata* conditions grouped.

Table 3. Countermovement jump test performance in different moments (10), styles (3) and conditions (2) during simulated kata competition (values are mean ± standard deviation; n = 30; 10 Shotokan, 10 Shitoryu, 10 Gojuryu athletes).

	Kata 1		***Kata 2***		***Kata 3***		***Kata 4***		***Kata 5***	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Control condition (cm)										
Shotokan	42.3 ± 4.9	41.6 ± 4.4	39.9 ± 4.2	39.8 ± 3.9	38.9 ± 3.9	38.9 ± 3.9	39.6 ± 3.6	39.8 ± 3.7	39.3 ± 3.8	40.0 ± 3.8
Gojuryu	43.2 ± 8.3	42.5 ± 8.1	41.8 ± 7.3	41.4 ± 6.5	40.0 ± 7.4	41.2 ± 7.1	41.8 ± 6.9	41.4 ± 6.6	40.7 ± 6.9	41.6 ± 6.1
Shitoryu	43.6 ± 5.3	43.2 ± 5.2	42.6 ± 4.7	42.8 ± 5.1	41.6 ± 4.2	42.4 ± 5.0	43.2 ± 5.1	43.1 ± 5.2	41.9 ± 5.0	43.3 ± 5.7
Total	**43.0 ± 6.2**	**42.4 ± 5.9**	**41.4 ± 5.5[g]**	**41.3 ± 5.2**	**40.2 ± 5.3[g]**	**40.8 ± 5.5[h]**	**41.5 ± 5.4[g]**	**41.4 ± 5.3**	**40.6 ± 5.3[g]**	**41.6 ± 5.3**
***Kata* condition (cm)**										
Shotokan	43.4 ± 4.4	42.9 ± 4.6	41.6 ± 4.9	42.1 ± 5.0	40.5 ± 4.4	42.6 ± 4.4	42.1 ± 4.5	43.1 ± 4.2	41.1 ± 3.4	43.4 ± 4.5
Gojuryu	41.8 ± 6.7	41.9 ± 6.4	40.5 ± 5.9	42.7 ± 6.7	41.1 ± 5.6	42.4 ± 6.3	41.9 ± 5.7	42.8 ± 6.7	40.9 ± 5.2	42.5 ± 6.3
Shitoryu	43.6 ± 3.6	43.5 ± 3.9	42.4 ± 4.6	42.8 ± 6.0	42.0 ± 5.4	42.5 ± 6.9	43.1 ± 6.2	43.2 ± 5.6	42.2 ± 5.6	44.7 ± 5.8
Total	**42.9 ± 5.0**	**42.8 ± 5.0**	**41.5 ± 5.1**	**42.5 ± 5.8**	**41.2 ± 5.0[i]**	**42.5 ± 5.7**	**42.3 ± 5.3**	**43.0 ± 5.4**	**41.4 ± 4.7[i]**	**43.5 ± 5.5[j]**
Control + kata conditions (cm)										
Total	**43.0 ± 5.5**	**42.6 ± 5.4**	**41.5 ± 5.2[a]**	**41.9 ± 5.5**	**40.7 ± 5.2[a]**	**41.7 ± 5.6[bd]**	**41.9 ± 5.3[ae]**	**42.2 ± 5.4**	**41.0 ± 5.0[ac]**	**42.6 ± 5.4[f]**

Notes: [a] effect of moment: decrease from pre 1 (p<0.05); [b] effect of moment: decrease from post 1 (p=0.025); [c] effect of moment: decrease from pre 4 (p=0.048); [d] effect of moment: increase from pre 3 (p=0.022); [e] effect of moment: increase from pre 3 (p<0.001); [f] effect of moment: increase from post 3 (p=0.040) and pre 5 (p<0.001); [g] effect of moment and condition interaction: decrease from Control pre 1 (p<0.05); [h] effect of moment and condition interaction: decrease from Control post 1 (p=0.008); [i] effect of moment and condition interaction: decrease from Kata pre 3 (p=0.002) and pre 5 (p=0.023); [j] effect of moment and condition interaction: increase from Kata pre 5 (p<0.001); control + *kata* condition (m) = mean ± standard deviation values obtained in control and *kata* conditions grouped.

Besides recognizing the benefits of warm-up in the countermovement jump (Bishop, 2003a; 2003b; Tsurubami et al., 2020) it is also important to understand how long this benefit can be maintained. Racinais, Cocking and Periard (2017) related that power and sprint athletes should have a recovery period between 5 to 10 min from the warm-up until the competition task to keep the potentiation benefits reached by the warm-up. In the present study, some recovery pauses were longer than the recommended duration. The intermittent stimulus of the *kata* 1 and 2 plus the sum of the first two 12-min recovery pauses (between *kata* 1 and 2 and *kata* 2 and 3) were not sufficient to keep the warm-up effects, causing a decrease in pre *kata* 3 performance. Similarly, the long 18 min recovery period resulted in lower performance pre *kata* 5 compared to pre *kata* 1. However, when there was a short 3-min interval before *kata* 4 there was no change in lower-body muscle power performance.

In fact, Tsurubami et al. (2020) analyzed the time course effects (immediately, 10 or 20 min after warm-up) on countermovement jump height performance and vastus lateralis muscle temperature after 15 min warm-up duration in different intensities (no warm-up, 60% $\dot{V}O_{2max}$, 80% $\dot{V}O_{2max}$). The authors observed an increase in muscle temperature and countermovement jump height for a 80% $\dot{V}O_{2max}$ warm-up intensity lasting 20 min. Concerning the 60% $\dot{V}O_{2max}$ warm-up, it was verified an improvement in countermovement jump height immediately after but no increase after 10 min. Moreover, the muscle temperature was significantly higher at 80% $\dot{V}O_{2max}$ compared to the 60% $\dot{V}O_{2max}$ condition. Therefore, the maintenance of the warm-up benefits seems to depend on the magnitude of the temperature rise added to how long this temperature continues to be elevated with both being influenced by the intensity of the warm-up task.

To our knowledge there are no studies about warming-up during the *kata* practice so a comparison was done with the present study and a Muay-Thai research. Cimadoro, Mahaffey & Babault (2018) investigated neuromuscular responses in nine Muay-Thai athletes in two conditions composed of 20 roundhouse kicks every 1 second (H1) and every 3 seconds (H3). Countermovement jump was measured immediately, 5, 10, 20 and 30 min after the series. There was a decrease in the H3 condition in all moments, whereas in the H1 condition this reduction was only seen in 20 and 30 min after the kicks series. The reduction in performance measured by the countermovement jump after H1 condition corroborates with the impairment in countermovement jump height in pre *kata* 3 and pre *kata* 5. In both studies a larger recovery pause caused a reduction in performance, which can be possibly explained by the decrease of the muscle temperature.

During the control condition, while the athletes remained in pause and did not practice *kata*, all lower-body performance values pre-control 2, 3, 4 and 5 were lower than pre-control 1. Once more, these results confirm the hypothesis that the loss of the warm-up benefits could justify the reduction in the values pre *kata* 3 and *kata* 5. These state and national athletes had better performance in the *kata* condition because they maintained the warm-up benefits they had reached and even the execution of the *kata* may have contributed to keep the temperature throughout the competition simulation (e.g., condition pre *kata* 4), whereas for the moments pre *kata* 3 and 5 the long accumulated intervals may have contributed to a decrease in body temperature (Bishop, 2003b).

Another important result was that the athletes of three styles and increased performance post *kata* 5 compared to pre *kata* 5. A possible explanation for the performance improvement post *kata* 5 is the occurrence of a phenomenon called post-activation potentiation (PAP). According to Tillin & Bishop (2009), the PAP is induced by a maximal or near maximal voluntary contraction used as a conditioning activity, increasing both peak force and rate of force development during the subsequent contraction. Thus, the intermittent *kata* exercise combining fast body displacements and powerful strikes such as kicks and jumps could have worked as a conditioning activity for this specialized sample. Loturco et al. (2017) reported that after one single *kumite* match one elite karate athlete improved the height of the countermovement jump when compared with pre-match value. Similarly, Chiodo et al. (2011) found better countermovement jump results after matches compared to pre-match values in an official taekwondo tournament.

An additional speculative justification for the increase in countermovement jump results post *kata* 5 compared to pre *kata* 5 in *kata* condition can be the self-regulation of the intensity of the effort called pacing strategy (Tucker & Noakes, 2009). This regulatory mechanism of the exercise intensity is related with previous experiences the athletes have attempted and it is done in order to preserve substrates and to avoid accumulating metabolites with the intention to finish the task required in the best way possible (Tucker & Noakes, 2009).

Although assessment tests applied during recovery pauses can not determine exactly whether the fatigue was caused by the competition stimulus, by the test itself or even the combination of both, it is a useful and objective measure commonly used in combat sports to verify how athletes deal with their competitive demands (Kraemer et al., 2001; Barbas et al., 2011; Chiodo et al., 2011; Bonitch-Góngora, Bonitch-Domínguez, Padial, & Feriche, 2012; Andreato et al., 2015; Julio et al., 2018).

For our knowledge, this is the first time that lower- and upper-body neuromuscular assessment tests were analyzed during a simulated *kata* competition. Muscle power is considered a key-element to karate in general (Chaabène, Hachana, Franchini, Mkaouer, & Chamari, 2012; Loturco, Artioli, Kobal, Gil, & Franchini, 2014), and *kata* athletes' success specifically (Doria et al., 2009). A limitation of this study is the controlled environment of the simulated competition, in which the athletes knew that they were not competing with their real adversaries, which can result in lower intensity during the execution of the technical gestures compared to that they would apply during an official competition. Additionally, the present study was driven only with male senior adult athletes, thus, younger and female categories need future investigation. Moreover, other studies can be conducted to verify upper-body responses during simulated kata competition including more sensitivity tests.

6. Conclusion

Kata competition did not interfere in the performance of the upper-body performance. Concerning lower-body muscle power performance, there was a decrease before *kata* 3 and before *kata* 5, probably because of a loss of the warm-up benefits. Conversely, there was a performance improvement after *kata* 5 regarding the pre *kata* 5, which can have happened due to a PAP or a strategy of regulation of the intensity during the simulated competition and tests. Besides, there were no differences between the three most popular styles *Shotokan*, *Shitoryu* and *Gojuryu*. These results provide a practical application to coaches and put in evidence that the performance can be improved when warm-up or PAP strategies are executed during *kata* competition. Moreover, in long recovery periods between *kata* a warm-up maintenance could be beneficial. More studies are needed to verify these effects.

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