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High-intensity interval training improves specific performance in taekwondo athletes

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ORIGINAL PAPER

Abstract
Specific training methods is an important aspect in the preparation of taekwondo athletes. The purpose of this study was to investigate the effect of a short-duration high-intensity interval training (HIIT) program with specific taekwondo techniques on anaerobic performance. Twelve taekwondo athletes were randomized into a control (n=6) or experimental groups (n=6). The experimental protocol consisted of 3 blocks of 6 sets of 10s all-out effort, with 10s passive recovery between sets and 1-min rest interval between blocks, conducted 3 days per week during 4-weeks. A three-way analysis of variance (ANOVA) (group, set and moment) with repeated measurements in the two last factors was conducted to compare the performance during each set of the Frequency Speed Kick Test (FSKT), and an ANOVA two-way (group and moment) with repeated measurements was used to compare the total number of kicks and kick decrement index (KDI). Both groups maintained their regular taekwondo training, which was exactly the same. Before and after the training program the athletes performed the FSKT. The experimental group increased (p<0.01) performance in each of the five sets of the FSKT and in the total number of kicks (p<0.001). No statistical difference was observed in the control group after 4-weeks or between the control and experimental group in any moment. A short-duration HIIT program with specific taekwondo techniques improved anaerobic performance measured through the FSKT. However, the fatigue index did not change.

Keywords: Combat sports; martial arts; taekwondo; HIIT; fatigue; athletic performance.

El entrenamiento intervalado de alta intensidad mejora el rendimiento específico en los atletas de taekwondo

Resumen
Los métodos de entrenamiento específicos son un aspecto importante en la preparación de los atletas de taekwondo. El propósito de este estudio fue investigar el efecto de un programa de entrenamiento intervalado de alta intensidad (EIAI) de corta duración con técnicas específicas de taekwondo sobre el rendimiento anaeróbico. Doce atletas de taekwondo fueron asignados al azar a un grupo control (n=6) o grupo experimental (n=6). El protocolo experimental consistió en 3 bloques de 6 series de esfuerzo

Treinamento intervalado de alta intensidade melhora desempenho específico em atletas de taekwondo

Resumo
Os métodos de treinamento específicos são um aspecto importante na preparação física dos atletas de taekwondo. O propósito deste estudo foi investigar o efeito de um programa de treinamento intervalado de alta intensidade (TIAI), de curta duração, com técnicas específicas de taekwondo sobre o desempenho anaeróbio. Doze atletas de taekwondo foram alocados aleatoriamente a um grupo controle (n=6) ou a um grupo experimental (n=6). O protocolo experimental consistiu em 3 blocos de 6 séries

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total de 10 segundos, con recuperación pasiva de 10 segundos entre series e intervalos de descanso de 1 minuto entre bloques, realizado 3 días por semana durante 4 semanas. Se realizó un análisis de varianza de tres vías (ANOVA) (grupo, serie y tiempo) con mediciones repetidas en los dos últimos factores para comparar el rendimiento durante cada serie de la prueba *Frequency Speed Kick Test* (FSKT) y un ANOVA de dos vías (grupo y tiempo) con mediciones repetidas se utilizó para comparar el número total de patadas y el *índice de fatiga de patadas* (IFP). Ambos grupos mantuvieron su entrenamiento regular de taekwondo, que era exactamente el mismo. Antes y después del programa de entrenamiento, los atletas realizaron el FSKT. El grupo experimental aumentó el rendimiento (p <0,01) en cada una de las cinco series de FSKT y en el número total de patadas (p <0,001). No se observó diferencia estadística en el grupo control después de 4 semanas o entre el grupo control y el grupo experimental en ningún momento. Un programa de EIAI de corta duración con técnicas específicas de taekwondo mejoró el rendimiento anaeróbico medido a través del FSKT. Sin embargo, el índice de fatiga no cambió.

Palabras clave: Deportes de combate; artes marciales; taekwondo; EIAI; fatiga; rendimiento atlético; HIIT.

de esforço com duração de 10 segundos, com recuperação passiva de 10 segundos entre as séries e intervalos de descanso de 1 minuto entre os blocos, realizado 3 dias por semana durante 4 semanas. Foi utilizada a análise de variância (ANOVA) a três fatores (grupo, série e tempo) com medidas repetidas nos dois últimos fatores para comparar o desempenho durante cada série do *Frequency Speed Kick Test* (FSKT) e uma ANOVA a dois fatores (grupo e tempo) com medidas repetidas foi utilizada para comparar o número total de chutes e o *índice de fadiga de chutes* (IFC). Os dois grupos mantiveram seu treinamento regular de taekwondo, o qual era exatamente o mesmo. Antes e depois do programa de treinamento os atletas realizaram o FSKT. O grupo experimental aumentou o desempenho (p <0,01) em cada uma das cinco séries do FSKT e no número total de chutes (p <0,001). Não foi observada diferença estatística no grupo controle depois de 4 semanas ou entre o grupo controle e o grupo experimental em nenhum momento. Um programa de TIAI, de curta duração, com técnicas específicas de taekwondo melhorou o desempenho anaeróbio medido por meio do FSKT. Contudo, o IFC não mudou.

Palavras-chave: Desportos de combate; artes marciais; taekwondo; TIAI; fatiga; desempenho atlético; HIIT.

1. Introduction

Taekwondo scoring actions are characterized by short-duration and high-intensity efforts, totaling approximately 15s of attack time per round and 47s of attack time in three rounds. However, studies investigating Hight Intensity Interval Training (HIIT) in combat sports used running as exercise mode (Franchini, Cormack, & Takito, 2019), and only two studies used combat sport-specific actions during this type of exercise (Franchini et al., 2016a; Kamandulis et al., 2018). Moreover, investigations about HIIT in combat sports used longer stimuli duration (i.e.,>30s) (Franchini et al., 2019) compared to the typical taekwondo scoring action or the typical effort-pause ratio observed in taekwondo matches (Bridge, Jones, & Drust, 2011; Bridge, McNaughton, Close, & Drust, 2013).

High-intensity interval training (HIIT) involves repeated short (<45 s) to long (2-4 min) bouts of rather high-intensity exercise interspersed with recovery periods (Buchheit & Laursen, 2013). Buchheit and Laursen (2013) categorized the HIIT in four main types: (a) *HIIT long intervals*, with efforts lasting longer than 1 min at intensities equivalent or just below maximal aerobic power, and work-to-rest ratios of 1:1, 1:2 or 1:3, with the main goal of aerobic power and anaerobic systems development; (b) *HIIT short intervals*, with efforts lasting less than 1 min at intensities equivalent to maximal aerobic power up to 120% of maximal aerobic power, and work-to-rest ratios of 1:1, 2:1 or 3:1, with the main goal of aerobic power and anaerobic systems development; (c) *repeated sprint training*, with very short actions (5-8 s) at intensities of approximately 120-160% of maximal aerobic power, with very long recovery periods (i.e.,>6 times longer than the effort duration), and directed to neuromuscular and metabolic development typically needed in team sports; and (d) *sprint interval training*, with typically 30-s efforts, executed in all-out mode, separated by 3 to 4 min intervals, resulting in very high oxidative and glycolytic demands.

In recent years some investigations have shown positive effects of HIIT in combat sports, like judo (Kim et al., 2011), karate (Ravier, Dugué, Grappe, & Rouillon, 2009), and Olympic wrestling (Farzad et al., 2011). Typically, these studies used training programs with intensities varying from submaximal efforts (80% of maximal aerobic velocity) to all-out efforts, with low volume lasting for 4 to 8 weeks, as this is the typical period that training can be intensified between successive competitions in combat sports (Franchini et al., 2019). However, these protocols have been carried out through non-specific exercises. Specificity is a training principle that is essential to ensure optimal adaptation and improve performance. In this context, three components of specificity should be considered for the prescription of training (energy system, muscle group, sports capacity) (Reilly, Morris, & White, 2009). However, only two studies (Franchini et al., 2016b;

Kamandulis et al., 2018) investigated the effects of combat sports-specific movement during HIIT in the physical performance. It has been shown that, in judo, a 4-week HIIT protocol using sport-specific techniques (*uchi-komi*) resulted in positive effects in peak power in upper and lower-body (Franchini et al., 2016b), in addition to showing improvements in a specific judo test called of "Special Judo Fitness Test" (Franchini et al., 2016a). In boxing, Kamandulis et al., (2018) demonstrated that 4-week of HIIT using a specific protocol "all-out", that is, maximum effort over a period of time (3 rounds of 14 sets of 3-s all-out punching bag with 10-s rest between sets and 1-min between rounds) resulted in increased peak oxygen consumption and peak power in a progressive arm-cranking test. During the simulated boxing match, they observed improved punching force and punching frequency maintenance for the experimental group compared to a control group. Despite these reports, specific training strategies that serve as a tool to improve performance-related characteristics in combat sports are lacking.

Recently, the effect of HIIT on athletic performance was investigated in taekwondo athletes (Monks, Seo, Kim, Jung, & Song, 2017). Taekwondo athletes were randomly divided into HIIT group or continuous running group. Both groups completed eleven sessions over 4-weeks. The HIIT protocols were prescribed mainly by running at 85~100% maximal heart rate, with active recovery periods of walking between bouts in sets of work/rest. The effort time in HIIT was around 30-s and 60-s. The study showed that HIIT was effective in producing significant improvements in anaerobic capacity. Significant improvement in anaerobic peak power, relative peak power, and mean power (p<0.05) were observed only in HIIT group compared to a group that exercised using continuous running. Additionally, improvement of aerobic power was observed in HIIT group (8.4%) compared to the continuous running group (1.7%). However, no research studying the specificity principle was found concerning HIIT in taekwondo, i.e., aspects such as body position, muscle activation, temporal structure and use of kicks were not investigated.

A recent specific test for taekwondo with intermittent characteristics called the *Frequency Speed of Kick Test* (FSKT) has been developed and used in taekwondo studies (Santos & Franchini, 2016, 2018; Santos, Herrera-Valenzuela, Mota, & Franchini, 2016; Santos, Loturco, & Franchini, 2018; Santos, Herrera-Valenzuela, & Franchini, 2015). This test has been used in two versions, a single 10s all-out bout and an intermittent version (five 10s all-out bouts interspersed by 10s intervals) (Santos & Franchini, 2018; Santos & Franchini, 2016; Santos et al., 2016; Santos et al., 2018; Santos et al., 2015). Although there is no evidence on the relationship of FSKT with anaerobic performance, other tests with all-out effort and similar duration are widely used as an indicator of anaerobic performance (Zagatto, Beck, & Gobatto, 2009). Additionally, this test has a similar effort-pause ratio to that observed in taekwondo matches (Bridge et al., 2011), and its total effort duration is only 50 s. Morevover, the FSKT was reported to present sensitivity to nine weeks of regular taekwondo training (Santos & Franchini, 2016). Therefore, until present moment, no study was conducted performing HIIT taekwondo-specific protocols using short-effort and pause periods (10-s effort/10-s pause) during the competitive period. Thus, the purpose of the present study was to investigate the effect of additional short-duration HIIT program using taekwondo-specific techniques executed intermittently measured through the FSKT. We hypothesize that a HIIT taekwondo-specific protocols using short-effort lasting 4 weeks can increase performance on the FSKT.

2. Methods

2.1. Experimental approach to the problem

The taekwondo athletes (n=12) were randomly allocated into control or experimental groups. The control group performed only taekwondo specific training during 4-weeks. The experimental group performed the same regular taekwondo training program as the control group and, additionally, a short-duration HIIT program using taekwondo-specific technique (*bandal tchagui*), three times a week during four weeks. The 4-week training program was set to cope with the typical interval that high-level taekwondo athletes have to conduct intensified training between competitions. As athletes normally take part in 8 to 10 competitions during the year, the high-intensity training (including HIIT and other training means) can be performed typically during four weeks. The athletes from control and experimental groups performed the $FSKT_{mult}$ before and after

the training period. All athletes involved in this study had experience with FSKT testing procedures. The test was executed in the training center where each athlete trained, during the competitive period. Before the testing session, a general and specific warm-up routine was performed. It was composed by running, stretching, and low-intensity kicks and punches totalizing approximately 15 minutes. The Figure 1 shows the experimental design. Participants were instructed to maintain their normal lifestyle and regular dietary intake during the study. All athletes had their last meal at least 2 hours before the test and were hydrated *ad libitum*. Additionally, they had 48 hours of rest before each test (pre and posttest) without consuming caffeine.

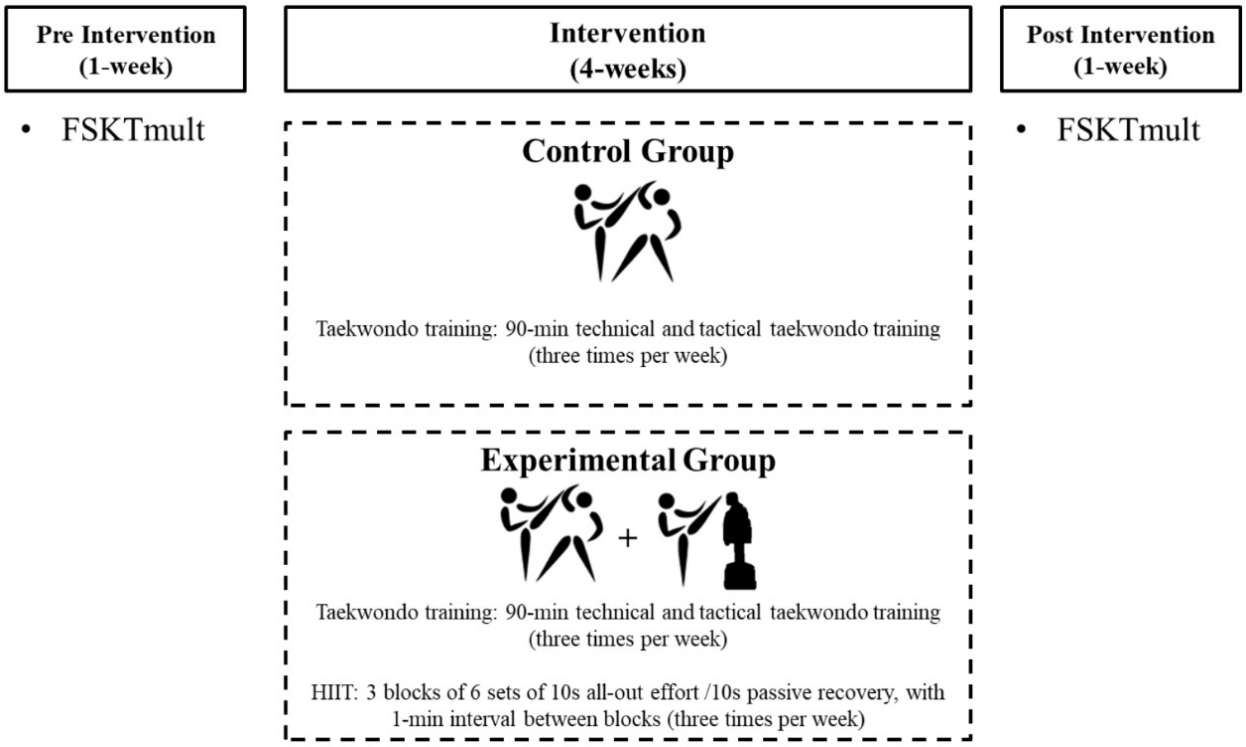

Figure 1. Experimental design including pre-measure, experimental period and post-measure. FSKTmult: frequency speed of kick test multiple sets.

2.2. Participants

Twelve national taekwondo athletes (two females and ten males) participated in this study. The control group was composed by six athletes (five males and one female) and the experimental group was composed by six athletes (five males and one female). Table 1 shows participants' demographic data. All were competitive taekwondo athletes and met the following inclusion criteria: a) greater than 3 year of taekwondo experience; b) training three or more times per week; c) having participated in national tournaments organized by the National Taekwondo Sports Federation (FEDENAT, Chile), an organization recognized by the World Taekwondo; d) enrolled in a club affiliated with FEDENAT; and e) provided an informed consent or provided an informed consent signed by their parent or guardian, in the case of minor participants, authorizing the use of the data for scientific purposes. None of them were reducing weight during the period this study was conducted, which was the in-season competition phase. The taekwondo athletes were free from any injury and neuromuscular disorder. All athletes or parents of athletes younger than 18 years provided written consent after being informed about the procedures and risks associated. This research was approved by the Institutional Ethics Committee.

Table 1. Participants' demographic data.

Group	Age (years)	Body mass (kg)	Height (m)	Practice time (years)
Control (*M*±*SD*)	21.3±5.6	75.9±11.4	1.74±0.09	4.2±0.4
Experimental (*M*±*SD*)	20.2±5.4	72.3±13.4	1.71±0.12	4.5±0.6

2.3. Regular taekwondo training

The control and experimental groups participated in the same regular taekwondo training sessions. Taekwondo training was conducted three times per-week during 4-weeks. Each training session lasted 90-min and consisted of technical and tactical exercises. The session began with a general warm-up, approximately 15-min and consisting of calisthenics exercises, followed by kicks and blows directed to an impact shield (Mooto, Korea), followed by a low-intensity taekwondo combat simulation. The main part of the training lasted 60-min and was composed of high-intensity tactical exercises to prepare the athlete for specific combat situations and a high-intensity combat simulation. The last 15-min included flexibility exercises. Intensity was controlled by the coach's indication to athletes (low or high intensity) and the type of task performed by the athletes, and the only difference in terms of training between the two groups was the addition of the HIIT for the experimental group.

2.4. High-intensity interval training (HIIT) protocol

The experimental group performed bandal tchagui for 3 blocks of 6 repetitions with duration of 10-seconds effort (all-out), interspersed by 10-seconds passive rest recovery between sets and 1-min of rest interval between blocks (Figure 1). The program lasted for 4-weeks, with training sessions 3-times per week. The experimental HIIT protocol was conducted 10-min after the taekwondo training session. An impact shield (Mooto, Korea) held by a training partner at the height of the performer's trunk was used as training material. Finally, recorded audio designed for this investigation was followed by the athletes.

2.5. Performance assessments

Multiple Frequency Speed of Kick Test ($FSKT_{mult}$). The $FSKT_{mult}$ was executed as described previously (Santos & Franchini, 2018; Santos & Franchini, 2016; Santos et al., 2016; Santos et al., 2015). The test is composed by 5 sets of 10s interspersed by 10s passive recovery. To perform the FSKT, each athlete was placed in front of the stand bag. After the sound signal, the participant performed the maximal number of kicks possible, alternating right and left legs. Intensity was controlled by the coach's indication to athletes (maximal effort). The performance was determined by the number of kicks in each set, total number of kicks, and kick decrement index (KDI) during the test. The KDI indicates that performance decreases during the test. To calculate the KDI, the number of kicks applied during the multiple FSKT was taken into account. $FSKT_{mult}$ presented high ICC between test-retest (ICC=0.85). The coefficient of variation between test-retest was 3.9%. The calculation was performed using an equation that takes into account the results of all FSKT sets (Equation 1) (Girard, Mendez-Villanueva, & Bishop, 2011; Santos & Franchini, 2018; Santos & Franchini, 2016; Santos et al., 2016; Santos et al., 2015).

2.6. Statistical analysis

The distribution of each variable was examined using the Shapiro-Wilk test. All variables had a normal distribution, except KDI in the control group. Data are presented as mean, standard deviation (SD) and 95% confidence interval for the differences. The Mauchly test was used to test the compound symmetry assumption and confirmed it. Thus, a three-way analysis of variance (group, set and moment) with repeated measurements in the two last factors was conducted to compare the performance during each set of the $FSKT_{mult}$, and a two-way analysis of variance (group and moment) with repeated measurements was used to compare the total number of kicks and KDI during the $FSKT_{mult}$. When interaction effect was found, the main effects were not reported. A Bonferroni test was used as post hoc. The differences between different moments or groups in different sets were not reported. All analyses were conducted using $\alpha=0.05$. The effect size (ES) was calculated through the Hedges´ g using the Hopkins tables (Hopkins, 2016).

3. Results

Table 2 presents the FSKT performances for the control and experimental groups, whereas Figure 2 presents the individual data.

Table 2. Performance during the Frequency of Speed Kick Test (FSKT) pre and post-training periods.

Variables	Control Group				Experimental Group			
	n Pre (*M±SD*)	n Post (*M±SD*)	ES (Pre vs Post)	95%CI (Post-Pre)	n Pre (*M±SD*)	n Post (*M±SD*)	ES (Pre vs Post)	95%CI (Post-Pre)
$FSKT_1$	18±4	18±3	0.00	-1.2; 0.9	18±2	20±2*	0.97	-0.1; 4.8
$FSKT_2$	18±3	18±3	0.00	0.0; 0.0	17±1	19±2*	1.22	0.2; 3.5
$FSKT_3$	17±3	17±3	0.00	-0.9; 0.2	16±1	19±2*	1.83	1.4; 4.6
$FSKT_4$	17±3	16±3	-0.32	-1.8; 0.4	16±2	19±2*	1.45	1.2; 4.1
$FSKT_5$	16±4	16±3	0.00	-1.9; 0.6	15±2	19±2*	1.93	1.6; 6.4
$FSKT_{total}$	86±16	84±15	0.13	-4.2; 0.5	81±8	95±9*	1.59	5.5; 22.2
KDI (%)	7.6±2.5	10.0±2.9	0.86	-2.47; 3.16	7.7±4.9	5.6±2.7	-0.51	-10.07; 5.35

*** *p*<0.05 from pre-training for the same variable in the same group. FSKT=frequency speed of kick test; KDI=kick decrement index. n: number of kicks. ES=effect size**

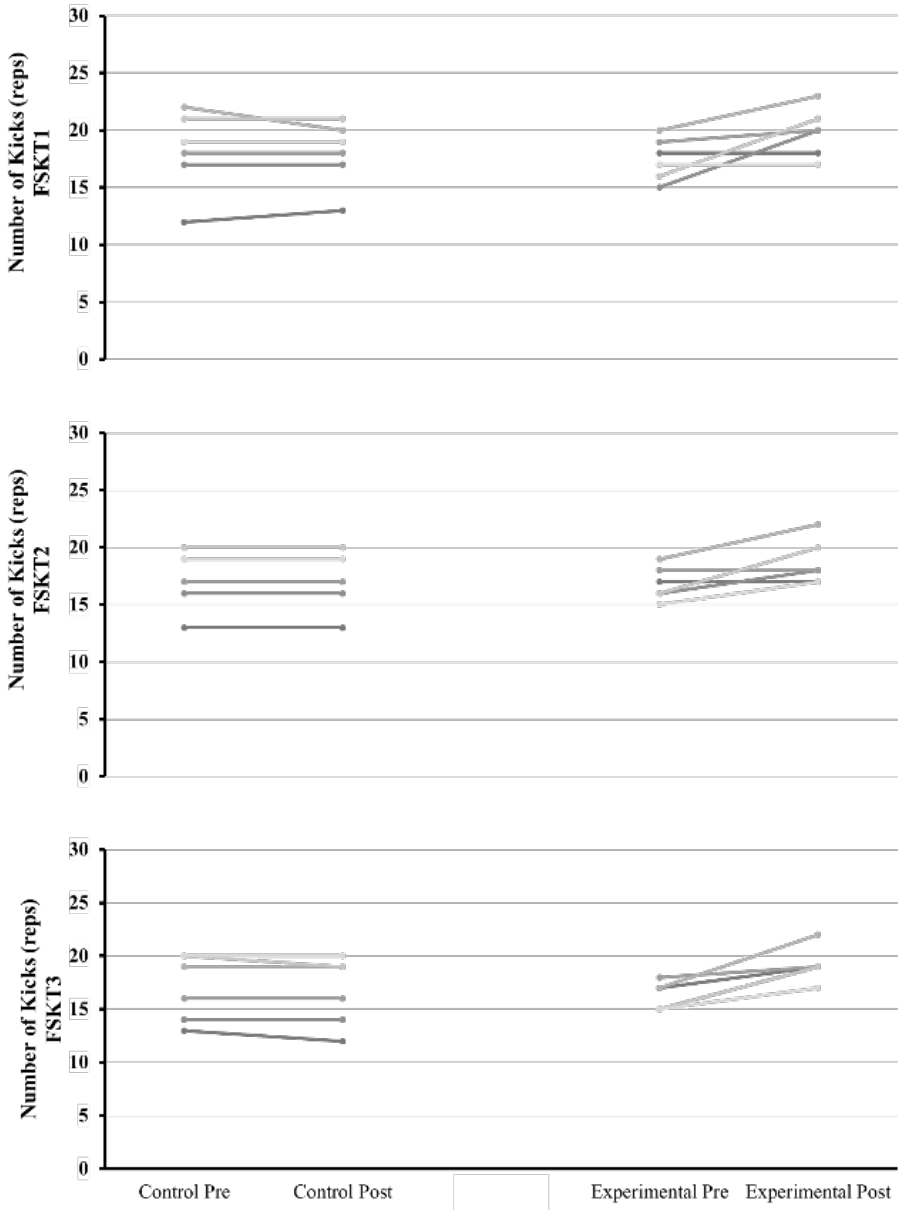

Figure 2(a). Individual performance during five sets of frequency speed of kick test (FSKT) and total number of kicks pre- and post-intervention. FSKTmult: frequency speed of kick test multiple sets.

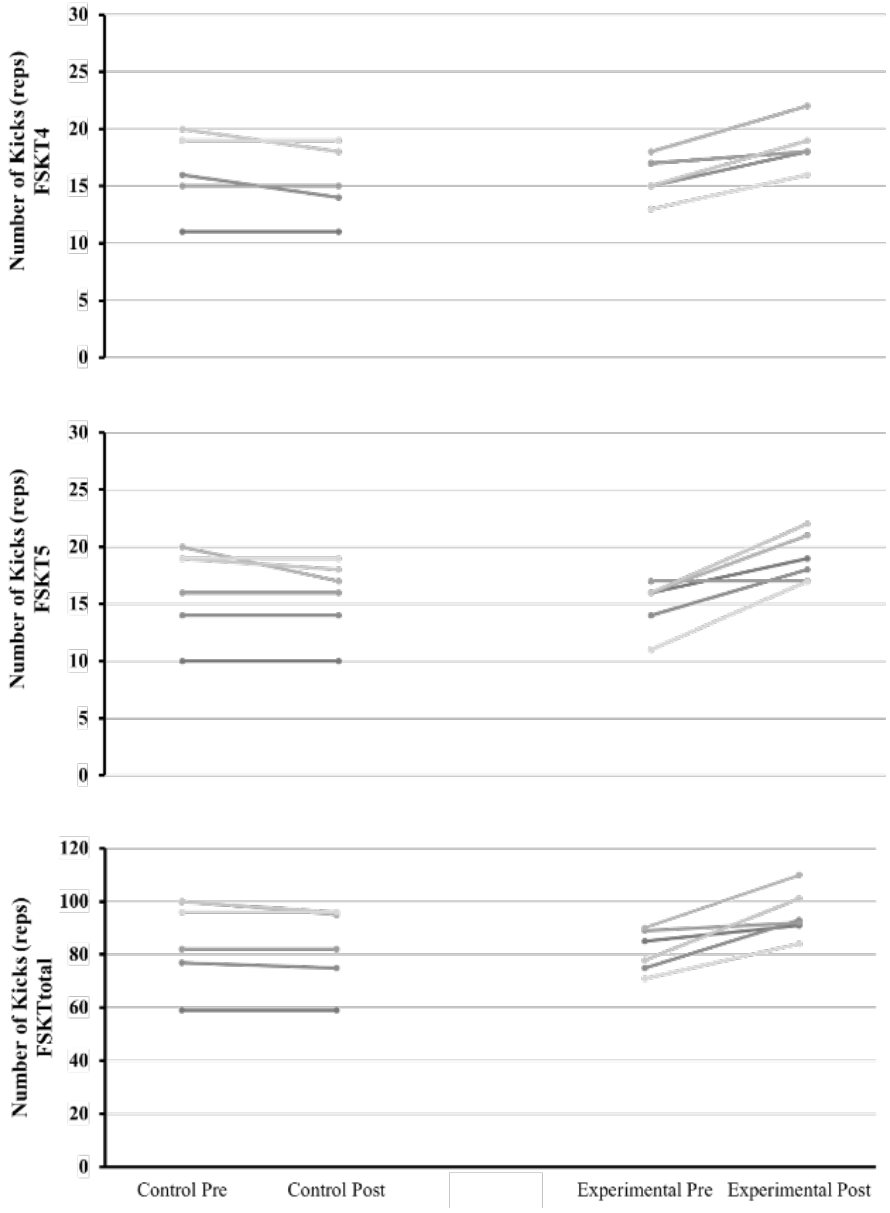

Figure 2(b). Individual performance during five sets of frequency speed of kick test (FSKT) and total number of kicks pre- and post-intervention. FSKTmult: frequency speed of kick test multiple sets.

There was a significant interaction effect between $FSKT_{mult}$, pre- and post-intervention, and group ($F_{4,40=}3.61$, p=0.013, observed power: 0.83). The contrasts revealed increased in performance post-intervention moment in $FSKT_1$ (p=0.010), $FSKT_2$ (p=0.003), $FSKT_3$ (p<0.001), $FSKT_4$ (p<0.001) and $FSKT_5$ (p<0.001) compared with the pre-intervention in experimental group. Differences between the pre- and post-intervention moments were not observed for the control group (p>0.05). There was no difference between groups comparing pre- or post-intervention (p>0.05).

In $FSKT_{total}$ there was interaction effect between moment and the group ($F_{1,10}$=21.43, p=0.001, observed power: 0.99). The contrasts revealed increase in the sum of the number of kicks at the post-intervention moment compared to the pre-intervention moment only in the experimental group (p<0.001). There was no difference between the groups at the pre- or post-intervention stage (p>0.05). No significant (p>0.361) effects or interaction were found for the KDI.

3. Discussion and conclusion

The purpose of the present study was to investigate the effect of additional short-duration HIIT program using taekwondo-specific techniques executed intermittently measured through the FSKT. The main result of this study was that 4-week HIIT program increased the number of kicks in each of the five sets of the FSKT and in $FSKT_{total}$.

Due to the duration time of FSKT-1 and FSKT-total, and the characteristics of maximum effort, the performance of both versions of FSKT can be considered an indicator of anaerobic performance. In this study, as in the study by Santos and Franchini (2016), we found significant differences after the training program. There were no differences between the groups before starting the experimental intervention; this shows that only an additional 8-min of HIIT using taekwondo-specific techniques improved the performance measured through the FSKT. However, there was no change in KDI. Moreover, control group did not alter the performance across the study, and no differences were observed between experimental and control groups at any moment. Previously, a 9-week study of taekwondo training also did not report KDI changes (Santos & Franchini, 2016). Therefore, it seems that it would not be a recommended variable to measure changes in athletes' performance or that only interventions inducing greater modification can be detected by this variable. This can be related to the fact that fatigue index during repeated sprint ability tests – which is the characteristic of the FSKTmult – presents higher variation and is less reliable than other variables in these tests such as mean power/velocity, total time or total number of repetitions (Lopes-Silva, Ferreira da Silva Santos, Abbiss, & Franchini, 2019).

Concerning anaerobic power and capacity, training protocols lasting between four and 8-weeks and reporting increased peak and mean power in the Wingate test in the experimental groups compared to control groups (Farzad et al., 2011; Franchini et al., 2016b; Kim et al; 2011; Monks et al., 2017). However, only the studies of Franchini et al. (2016a) and Kamandulis et al., (2018) used a combat sport-specific training and testing protocols, in an investigation with judo and boxing athletes, respectively. Thus, the main contribution of the present study was to provide evidence that a taekwondo-specific HIIT protocol was able to increase performance measured with FSKT in only 4-weeks. Ravier et al. (2009) reported increased maximal accumulated oxygen deficit in karate athletes submitted to seven weeks of HIIT plus usual karate training, while Monks et al. (2017) compared taekwondo athletes submitted to HIIT or high-intensity continuous running (HICR) for 4-weeks, and found higher improvement in Wingate Test for the HIIT group compared to the HICR group. The findings from Monks et al. (2017) are relevant considering that performance during the Wingate test is superior in higher level competitive taekwondo athletes compared with lower level competitors (Sadowski, Gierczuk, Miller, & Cieśliński, 2012). Thus, our study is supported by previous studies conducted with karate and taekwondo athletes submitted to running HIIT and who improved their anaerobic power and capacity in non-specific tests.

The protocol used in the present study could serve to improve the anaerobic performance, represented by total FSKT. The athletes in the present study did not show improvements in KDI, although they increased the number of repetitions in total number of *bandal tchagui* kicks, similar to what was reported in a previous study (Santos & Franchini, 2016). Thus, the KDI does not respond to training in the same way as the total number of kicks.

In practical terms, this research gives taekwondo coaches a tool for improving anaerobic performance, using a specific short-duration training program, with a temporal structure similar to that found during competition and with the same duration of one combat match. Among the strengths of the study was the design that allowed having a control group with similar characteristics as the experimental group, the simplicity of the tests that can be replicated by trainers and instructors of the specialty without requiring expensive equipment. As a limitation, we acknowledge the small number of athletes (10 men and two women), age-range and differences in terms of experience, however, having larger samples in competitive sports is difficulty, especially when national and international level athletes are evaluated.

A high-intensity, short-duration interval training program with specific taekwondo techniques resulted in improvements in anaerobic performance measured through the FSKT. However, the fatigue index did not improve. Thus, in only four weeks additional HIIT was able to improve taekwondo-specific anaerobic and high-intensity intermittent performance, suggesting that strength and conditioning taekwondo coach could use a similar structure to improve anaerobic performance of taekwondo athletes when approaching relevant competitions or when a short training period is available before tournaments.

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References

Bridge, C.A., Jones, M.A., & Drust, B. (2011). The activity profile in international Taekwondo competition is modulated by weight category. *International Journal of Sports Physiology and Performance, 6*(3), 344-357. doi:10.1123/ijspp.6.3.344

Bridge, C.A., McNaughton, L.R., Close, G.L., & Drust, B. (2013). Taekwondo exercise protocols do not recreate the physiological responses of championship combat. *International Journal of Sports Medicine, 34*(7), 573-581. doi:10.1055/s-0032-1327578

Buchheit, M., & Laursen, P. (2013). High-intensity Interval Training, Solutions to the Programming Puzzle: Part I: Cardiopulmonary Emphasis. *Sports Medicina, 43*(10), 927-54. doi:10.1007/s40279-013-0066-5

Farzad, B., Gharakhanlou, R., Agha-Alinejad, H., Curby, D.G., Bayati, M., Bahraminejad, M., et al. (2011). Physiological and performance changes from the addition of a sprint interval program to wrestling training. *Journal of Strength and Conditioning Research*, *25*(9), 2392-2399. doi:10.1519/JSC.0b013e3181fb4a33

Franchini, E., Julio, U.F., Panissa, V.L.G., Lira, F.S., Agostinho, M.F., & Branco, B.H.M. (2016a). Short-term low-volume high-intensity intermittent training improves judo-specific performance. *Archives of Budo, 12*, 219-229. doi:10.1016/j.jsams.2017.01.199

Franchini, E., Julio, U.F., Panissa, V.L., Lira, F.S., Gerosa-Neto, J., & Branco, B.H. (2016b). High-intensity intermittent training positively affects aerobic and anaerobic performance in judo athletes independently of exercise mode. *Frontiers in Physiology, 28*(7), 268. doi:10.3389/fphys.2016.00268

Franchini, E., Cormack, S., & Takito, M. Y. (2019). Effects of High-Intensity Interval Training on Olympic Combat Sports Athletes' Performance and Physiological Adaptation: A Systematic Review. *Journal of Strength and Conditioning Research*, *33*(1), 242–252. doi:10.1519/JSC.0000000000002957

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-sprint ability - part I: Factors contributing to fatigue. *Sports Medicine, 41*(8), 673-694. doi:10.2165/11590550-000000000-00000

Hopkins, W.G. (2016). A new view of statistics: A scale of magnitude for effect statistics. Retrieved July 5, 2017 from http://www.sportsci.org/resource/stats

Kamandulis, S., Bruzas, V., Mockus, P., Snieckus, A., & Venckunas, T. (2018). Sport-specific repeated sprint training improves punching ability and upper-body aerobic power in experienced amateur boxers. *Journal of Strength and Conditioning Research, 32*(5), 1214–1221. doi:10.1519/JSC.0000000000002056

Kim, J., Lee, N., Trilk, J., Kim, E.J., Kim, S.Y., Lee, M., et al. (2011). Effects of sprint interval training on elite judoists. *International Journal of Sports Medicine, 32*(12), 929-934. doi:10.1055/s-0031-1283183

Lopes-Silva, J.P., Ferreira da Silva Santos, J., Abbiss, C., Franchini, E. (2019). Measurement Properties and Feasibility of Repeated Sprint Ability Test: A Systematic Review. *Strength & Conditioning Journal, 41*(6), 41-61. doi:10.1519/SSC.0000000000000495

Monks, L., Seo, M.W., Kim, H.B., Jung, H.C., & Song, J.K. (2017). High-intensity interval training and athletic performance in taekwondo athletes. *The Journal of Sports Medicine and Physical Fitness, 57*(10), 1252-1260. doi:10.23736/S0022-4707.17.06853-0

Ravier, G., Dugué, B., Grappe, F., & Rouillon, J.D. (2009). Impressive anaerobic adaptations in elite karate athletes due to few intensive intermittent sessions added to regular karate training. *Scandinavian Journal of Medicine & Science in Sports, 19*(5), 687-694. doi:10.1111/j.1600-0838.2008.00807.x

Reilly, T., Morris, T., & Whyte, G. (2009). The specificity of training prescription and physiological assessment: a review. *Journal of sports sciences*, *27*(6), 575–589. doi: 10.1080/02640410902729741

Sadowski, J., Gierczuk, D., Miller, J., & Cieśliński, I. (2012). Success factors in elite WTF taekwondo competitors. *Archives of Budo, 8*(3), 141-146.

Santos, J.F.S., & Franchini, E. (2018). Frequency speed of kick test performance comparison between female taekwondo athletes. *Journal of Strength and Conditioning Research, 32*(10), 2934-2938. doi:10.1519/JSC.0000000000002552

Santos, J.F.S., & Franchini, E. (2016). Is frequency speed of kick test responsive to training? A study with taekwondo athletes. *Sport Sciences for Health, 12*(3), 377-382. doi:10.1007/s11332-016-0300-2

Santos, J.F.S., Herrera-Valenzuela, T.H., & Franchini, E. (2015). Can different conditioning activities and rest intervals affect the acute performance of taekwondo turning kick? *Journal of Strength and Conditioning Research, 29*(6), 1640-1647. doi:10.1519/JSC.0000000000000808

Santos, J.F.S., Herrera-Valenzuela, T., Mota, G.R., & Franchini, E. (2016). Influence of half-squat intensity and volume on the subsequent countermovement jump and frequency speed of kick test performance taekwondo athletes. *Kinesiology, 48*(1), 95-102. doi:10.26582/k.48.1.6

Santos, J.F.S., Loturco, I., & Franchini, E. (2018). Relationship between frequency speed of kick test performance, optimal load, and anthropometric variables in black-belt taekwondo athletes. *Ido Movement for Culture. Journal of Martial Arts Anthropology, 18*(1), 39-44. doi:10.14589/ido.18.1.6

Zagatto, A. M., Beck, W. R., & Gobatto, C. A. (2009). Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *Journal of Strength and Conditioning Research*, *23*(6), 1820–1827. doi:10.1519/JSC.0b013e3181b3df32

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