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Human Kinetics
BRIEF REPORT

High-Intensity Interval Training Prescription for Combat-Sport Athletes

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Context: Combat sports are composed of high-intensity actions (eg, attacks, defensive actions, and counterattacks in both grappling and striking situations depending on the specific sport) interspersed with low-intensity actions (eg, displacement without contact, stepping) or pauses (eg, referee stoppages), characterizing an intermittent activity. Therefore, high-intensity interval training (HIIT) is at the essence of combat-sport-specific training and is used as complementary training, as well. HIIT prescription can be improved by using intensity parameters derived from combat-sport-specific tests. Specifically, the assessment of physiological indexes (intensity associated with the maximal blood lactate steady state, maximal oxygen consumption, and maximal sprint) or of time–motion variables (high-intensity actions, low-intensity actions, and effort:pause ratio) is a key element for a better HIIT prescription because these parameters provide an individualization of the training loads imposed on these athletes. ***Purpose:*** To present a proposal for HIIT prescription for combat-sport athletes, exemplifying with different HIIT protocols (HIIT short intervals, HIIT long intervals, repeated-sprint training, and sprint interval training) using combat-sport-specific actions and the parameters for the individualization of these protocols. ***Conclusions:*** The use of combat-sport-specific tests is likely to improve HIIT prescription, allowing coaches and strength and conditioning professionals to elaborate HIIT short intervals, HIIT long intervals, repeated-sprint training, and sprint interval training protocols using combat-sport actions, providing more specificity and individualization for the training sessions.

Keywords: specificity, intermittent, exercise prescription

Combat sports will represent around 25% of the medals to be disputed in the 2021 Tokyo Olympic Games, including disputes in boxing, fencing, judo, karate, taekwondo, and wrestling.[1] Many countries invest enormous amounts of money to prepare their athletes, and the direction of the training process is becoming more and more science driven to increase the predictability of improvements and justify such investments.[2]

Combat sports are characterized by high-intensity intermittent actions interspersed by low-intensity recovery actions or referee stoppage. Olympic combat sports can be divided into weapon based (ie, fencing); striking (ie, boxing, karate, and taekwondo); and grappling (ie, judo and wrestling) combat sports. In each of these sports, distinct techniques are allowed and prohibited (eg, boxing and taekwondo are striking combat sports, but in the first kicking techniques are not allowed, whereas in the later punching techniques are allowed but much less executed than kicking techniques), resulting in a very specific work-to-rest ratio[3–8] and physiological demands.[9–13] Therefore, the training process for each combat sports must be tailored for its demands.[11,12,14]

To better understand the physiological demands of combat sports, several approaches have been used, but the main strategies to increase the knowledge concerning the physiological needs of top-level athletes include the following: (1) to investigate the physiological profile of elite athletes and to compare them with lower-level athletes,[15] (2) to determine the time–motion analysis of top-level competitions,[6] and (3) to conduct physiological measurements in simulated or official competitions.[5] In the past 2 decades, there was an increase in the number of investigations providing information concerning the physiological profiles, work-to-rest ratio, and energy systems contributions of each of the Olympic combat sports, including reviews reporting most of the indexed research published so far, for boxing,[11] fencing,[7] judo,[13] karate,[10] taekwondo,[9] and wrestling.[12]

To achieve success in combat sports, athletes need to develop both aerobic and anaerobic pathways to cope with the action demands during the matches. High-intensity interval training (HIIT) has been reported to be able to develop the different energy systems in a time-efficient approach.[16,17] Indeed, the use of HIIT in Olympic combat sports was recently reported to be efficient to improve both aerobic and anaerobic fitness of the fighters.[18] The understanding of the foundations to combat sports-specific HIIT prescription is a key element to improve combat sports athletes physical fitness while guaranteeing that the specificity principle is assured.[18] Therefore, in the present review, the main time–motion studies presenting the work-to-rest ratio of high-level combat sports official matches, the energy systems contributions, and HIIT protocols are summarized, and indications on how to prescribe these protocols using combat-sports specific tests and time structure are reported.

Work-to-Rest Ratio in High-Level Combat-Sport Official Matches

The rules of each combat sport create constraints that generate distinct technical–tactical behaviors. These behaviors are also influenced by the technical skills and physical fitness of the 2 athletes competing in a given match, generating a specific pacing for the combat.[19] This interaction also results in very specific physiological demands. Therefore, the combat sports athletes training is focused mainly on the development of technical–tactical

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skills, but it is important to consider that these technical–tactical actions are supported by highly developed physical fitness.[5,20,21] The determination of the official combat sports work-to-rest ratio is an easy and relevant source of information to infer its physiological demands and to provide valuable information to the prescription of specific HIIT protocols. Table 1 presents studies that analyzed World Championships and Olympic Games work-to-rest ratio of high-level Olympic combat sports matches.

For high-level taekwondo matches, the work-to-rest ratio is 1:1, but high- to low-intensity ratio may vary from 1:3 to 1:7.[3,27] A similar scenario was observed in high-level karate competition; that is, the work-to-rest ratio is approximately 1:1.5, but activity phases contained 32.8 (8.3) high-intensity actions per fight, lasting 1 to 3 seconds each, which resulted in high-intensity actions to pause ratio of 1:8.[8] Boxing is the single Olympic striking combat sport in which only punches are permitted. Davis et al[28] found an overall work-to-rest ratio of 9:1 (excluding intervals between rounds). Thus, when striking combat sports are considered globally, a wide variation is observed, from 9:1 for boxing to 1:1.5 for karate. Moreover, when the high- to low-intensity action ratio is considered, a more intermittent in pattern was reported (eg, 1:7 in taekwondo).

In high-level judo competitions, the mean time duration of each sequence of activity and pause is approximately 13 to 29 seconds and 5 to 11 seconds,[25,26] respectively, resulting in a 2.6:1 to 2.8:1 work-to-rest ratio. An investigation analyzing Greco-Roman Wrestling World Championship[6] reported that the combat phases lasted approximately 30 seconds, and pause phases were around 10 seconds, generating a 3:1 work-to-rest ratio. Thus, Olympic grappling combat sports typically present a work-to-rest ratio around 3:1.

Fencing is the single weapon-based Olympic combat sport, disputed with 3 different weapons (foil, épée, and sabre), but no investigations analyzing World Championships or Olympic Games time–motion were found. Studies carried out in international competition have reported work-to-rest ratio of 1:1 in males épée, 2:1 in females épée, and 1:3 in males foil,[7] whereas Wylde et al[29] reported 1:1.1 for females foil. For sabre, World Cup elimination bouts resulted in 1:6 (1:6.5 for males and 1:5.1 for females) work-to-rest ratio.[30]

Energy-System Contributions During Olympic Combat Sports

The knowledge of the metabolic profile of a given combat sport constitutes a valuable information to elaborate specific training programs. As combat sports are characterized by frequent contact between opponents because the adversary's body is the target in such modalities, the execution of continuous physiological measurements—especially gas analysis—during official matches is not possible with the current technology. However, despite this limitation, some investigations used simulated matches to estimate the energy systems contributions during different Olympic combat sports, including boxing,[31] judo,[32] karate,[33,34] and taekwondo.[35–37] The main findings concerning the energy systems contributions in these combat sports are presented in Table 2.

Despite the different technical–tactical and time structure characteristics between the Olympic combat sports, the oxidative pathway is the main source of energy during the combats, followed by the adenosine triphosphate and phosphocreatine (ATP-PCr) and glycolytic systems. It is likely that the powerful actions executed to score in combat sports are supported by the phosphagen system, which makes it the second main source of energy, while the oxidative system provide the energy for lower intensity actions and for the PCr restoration between successive high-intensity actions. The glycolytic system seems to be involved in the beginning of the matches and when high-intensity actions are executed successively during the match. Moreover, the estimated metabolic power is similar among the combat sports, with considerable overlap between combat sports. Conversely, whereas in taekwondo, athletes seem to increase the metabolic power in the last round[35–37]; it decreases along the typical judo match[32] and along successive matches in karate.[33]

So far, the energy systems contributions were not investigated only fencing and wrestling among the Olympic combat sports. Conversely, the effects of nutritional ergogenic aids (ie, caffeine and sodium bicarbonate) on the energy systems contributions were verified in taekwondo,[36,37] indicating that the estimated energy systems contributions can be used to verify the effects of different interventions (eg, acute and chronic nutritional and pharmacological interventions, training protocols and recovery procedures between matches).

HIIT Protocols

There are different classifications of HIIT protocols, but the proposal by Buchheit and Laursen[16] has been used by researchers because it presents sound scientific basis and by coaches because it allows an easy decision making for most of the desired training adaptations. Table 3 presents a synthesis of the 4 protocols suggested by these authors and the main variables that can be manipulated to organize the HIIT sessions.

Buchheit and Laursen[16,17] presented some physiological and mechanical parameters to increase the individualization of the HIIT prescription. Briefly, to prescribe the first 3 protocols showed in Table 3, strength and conditioning professionals should have the following parameters in the exercise mode chosen for the training sessions: (1) maximal sprint speed or power; (2) maximal aerobic speed or power; and (3) maximal lactate steady-state speed or power, or other submaximal index (eg, critical power or velocity, ventilatory thresholds, lactate thresholds, onset of blood lactate accumulation, respiratory compensation point) and its associated intensity in terms of velocity or power. Moreover, with maximal sprint speed or power and maximal aerobic speed or power, it is possible to calculate the anaerobic speed or power reserve, which has been reported to decrease the performance and physiological responses variability during 1 HIIT protocol.[38]

Recently, many combat sports-specific tests were created and validated,[39] and therefore, they can be used to prescribe sport-specific HIIT protocols, assuring that a key training principle—the specificity principle—is achieved.[16,17] For the HIIT long intervals, the utilization of the delta 40% between the gas exchange threshold and the maximal aerobic power was reported to result in better training individualization[40]—another key training principle[16,17]—than using fixed percentages (50%, 70%, or 90% maximal oxygen consumption). Specifically, Lansley et al[40] demonstrated that the use of this delta decreased the intersubject variability in pulmonary gas exchange, blood lactate, heart rate, and rating of perceived exertion. Thus, the use of the delta over the percentages of maximal oxygen consumption was recommended by these authors. Therefore, a similar approach should be used when using combat sports-specific exercises. Moreover, Julio et al[38] analyzed the use of the anaerobic speed reserve during running, that is, the difference between maximal sprint speed and maximal aerobic speed, to

Table 1 Effort and Pause Duration and Work-to-Rest Ratio in High-Level Olympic Combat-Sport Matches

Sport, study	Competition information	Groups	Effort duration, s	Pause duration, s	Work-to-rest ratio
Boxing					
Davis et al[4]	London 2012 OG (10 final and 19 semifinal bouts and 39 male athletes)				18:1
Davis et al[22]	London 2012 OG and the Association of International Amateur Boxing Worlds 2012 (6 final and 12 semifinal bouts and 24 female athletes)				6.6:1
Judo					
Castarlenas and Planas[23]	1991 World Judo Championship, 144 male matches	Males	18.00 (8.48)	12.42 (4.07)	1.5:1
Challis et al[24]	2010 Worlds, female competition, 143 contests of under 48-, 52-, and 57-kg weight categories	<48 kg	21.7 (6.8)	8.1 (3.4)	2.7:1
		52 kg	23.1 (6.5)	8.2 (3.3)	2.8:1
		57 kg	26.4 (14.3)	8.4 (3.4)	3.1:1
Miarka et al[25]	London 2012 OG 56 winning combats and 56 losing combats performed by the best 22 male athletes from each weight category	Winning matches	13.5 (7.5)	4.8 (2.9)	2.8:1
		Losing matches	13.1 (5.4)	5.0 (2.7)	2.6:1
Miarka et al[26]	London 2012 OG 60 winning combats and 64 losing combats performed by the best 14 female athletes from each weight category	Winning matches	29.0 (16.0)	11.2 (5.0)	2.6:1
		Losing matches	28.4 (11.5)	10.3 (4.7)	2.8:1
Karate					
Tabben et al[8]	2012 Worlds, 60 matches analyzed (males 4-min matches, n = 30; females 3-min matches, n = 30), lightweight (n = 24): male <60 and <67 kg, female <50 and <55 kg; middle weight (n = 24): male <75 and <84 kg, female <61 and <68 kg; and heavyweight (n = 12) = male >84 kg, female >68 kg	Males		Males	
		Fighting winners	1.6 (0.3)	Winners = 12.3 (4.3)	0.8:1
		Fighting defeated	1.5 (0.3)	Defeated = 11.9 (3.6)	
		Preparatory winners	7.6 (2.1)	Females	0.8:1
		Preparatory defeated	7.6 (2.1)	Winners = 11.6 (9.9)	
		Females		Defeated = 9.1 (2.9)	
		Fighting winners	1.3 (0.1)	All	0.7:1
		Fighting defeated	1.3 (0.2)	Light = 10.7 (2.8)	
		Preparatory winners	7.3 (2.5)	Middle = 13.3 (8.2)	0.9:1
		Preparatory defeated	6.8 (2.2)	Heavy = 8.1 (2.0)	
		All			
		Fighting light	1.4 (0.2)		0.8:1
		Fighting middle	1.4 (0.3)		0.7:1
		Fighting heavy	1.5 (0.2)		1.2:1
		Preparatory light	7.2 (2.5)		
		Preparatory middle	7.2 (1.8)		
		Preparatory heavy	7.9 (2.5)		

(continued)

Table 1 ***(continued)***

Sport, study	Competition information	Groups	Effort duration, s	Pause duration, s	Work-to-rest ratio
Taekwondo					
Bridge et al[3]	2005 Worlds, 18 males matches analyzed	R1	NR	2.0 (1.9)	7.8:1
		R2		3.0 (0.9)	5.5:1
		R3		2.9 (0.9)	4.9:1
		<54 kg		2.9 (0.8)	6.4:1
		67 kg		3.4 (0.9)	7:01
		>84 kg		3.0 (0.8)	5.5:1
		All		2.8 (0.9)	6.3:1
Santos et al[27]	2007 Worlds, 22 matches analyzed (65 rounds, 13 semifinals, and 8 finals) and Beijing 2008 OG, 23 matches analyzed (63 rounds, 22 rounds with 16 athletes each, and 1 quarterfinal round), males only in both competitions	Worlds	NR	5.1 (2.9)	2.2:1
		OG		7.0 (4.5)	2.3:1
		Both		6.0 (3.9)	2.3:1
		Gold/silver Worlds (n =16)		6.8 (4.4)	2.2:1
		Bronze Worlds (n = 14)		7.3 (4.7)	2.2:1
		Medalists OG (n = 10)		5.0 (3.2)	2.7:1
		Nonmedalists OG (n = 38)		5.1 (2.8)	2.1:1
		Worlds R1		4.9 (4.0)	3.4:1
		Worlds R2		7.4 (3.7)	1.9:1
		Worlds R3		8.8 (5.0)	1.4:1
		OG R1		4.6 92.3)	2.8:1
		OG R2		4.8 (3.2)	2.4:1
		OG R3		6.2 (3.0)	1.5:1
		Worlds < 54 kg		9.7 (5.8)	1.4:1
		Worlds 58 kg		6.8 (2.8)	1.7:1
		Worlds 62 kg		8.6 (5.0)	2:01
		Worlds 67 kg		5.9 (4.7)	2.9:1
		Worlds 72 kg		4.3 (2.0)	2.6:1
		Worlds 78 kg		4.9 (1.5)	2.5:1
		Worlds 84 kg		9.2 (6.6)	2.4:1
		Worlds > 84 kg		7.0 (2.5)	2.3:1
Wrestling					
Nilsson et al[6]	1998 Greco-Roman Wrestling Worlds (N = 42 wrestlers who disputed 94 matches)	All	37.2 (9.8)	13.8 (6.0)	2.7:1

Abbreviations: NR, not reported; OG, Olympic Games; R1–R3, rounds 1–3; Worlds, World Championship. Note: Values are represented as mean (SD). Differences between rounds, weight categories, and competitions were omitted because of the goals of the present review.

Table 2 Energy-System Contributions and Metabolic Power in Olympic Combat Sports

Sport, study	Combat characteristics	Match/round/duration	Oxidative, kJ	Glycolytic, kJ	ATP-PCr, kJ	Total, kJ	Oxidative, %	Glycolytic, %	ATP-PCr, %	Metabolic power, kW
Boxing										
Davis et al[31]	3 × 2-min/1-min, semicontact bout against handled pads using the time–motion from Davis et al,[31] ie, 9:1 work-to-rest ratio. Total time = combat time + 11% (based on the work-to-rest ratio) + breaks (~520 s). Male athletes.	Round 1	126.8 (20.3)	13.5 (4.1)	NE	608.6 (81.8)	86 (NR)	4 (NR)	10 (NR)	1.17 (0.01)
		Round 2	141.6 (24.0)	8.4 (2.5)	NE					
		Round 3	140.9 (28.6)	4.3 (3.5)	NE					
		Break 1	56.2 (6.5)	NE	NE					
		Break 2	60.5 (7.3)	NE	NE					
		Total	526.0 (27.1)	26.2 (7.1)	58.1 (13.6)					
Judo										
Julio et al[32]	1- to 5-min matches. Work-to-rest ratio = approximately 3:1. Therefore, 20 s were added for each 1 min of match (ie, 1-min match = 80 s; 2-min match = 160 s; 3-min match = 240 s; 4-min match = 320 s; 5-min match = 400 s). Male athletes.	1 min	56.6 (16.2)	11.2 (6.0)	45.2 (11.3)	113.0 (33.6)	50 (9)	10 (4)	40 (7)	1.88 (0.42)
		2 min	107.5 (33.4)	17.5 (9.3)	42.7 (19.7)	167.7 (62.4)	65 (8)	10 (4)	25 (7)	1.40 (0.39)
		3 min	193.0 (58.2)	16.7 (8.6)	40.2 (17.4)	249.9 (84.2)	77 (6)	7 (4)	16 (6)	1.39 (0.35)
		4 min	275.4 (63.9)	23.5 (7.9)	51.1 (19.2)	350.0 (91.0)	79 (6)	7 (2)	14 (4)	1.46 (0.28)
		5 min	315.1 (114.7)	23.9 (9.3)	47.0 (22.7)	386.1 (146.6)	81 (4)	6 (2)	12 (4)	1.29 (0.37)
Karate										
Beneke et al[33]	Work-to-rest-ratio = 2:1. Therefore, matches 1–4 have a mean total duration of 260, 243, 277, and 290 s, respectively. Male athletes.	Match 1	267.4 (69.8)	28.3 (7.8)	52.6 (9.9)	348.3 (74.5)	77.8 (5.8)[a]	6.2 (2.4)	16.0 (4.6)	1.34 (0.14)
		Match 2	258.8 (49.8)	23.5 (4.6)	56.2 (11.8)	338.5 (55.8)				1.39 (0.10)
		Match 3	256.2 (87.2)	15.5 (5.1)	48.6 (13.0)	320.3 (99.1)				1.16 (0.10)
		Match 4	266.6 (113.0)	12.3 (8.4)	48.8 (15.4)	327.7 (12.1)				1.13 (0.20)
Doria et al[34]	No information about work-to-rest ratio. 1 match. Only total duration was reported: males = 4 min; females = 3 min. Male and female Word Championship medal winners.	Males	225.5 (20.4)	36.1 (10.4)	43.3 (11.0)	304.8 (25.5)	74 (1)	12 (2)	14 (3)	1.27 (0.11)
		Females	113.4 (26.2)	37.8 (18.2)	33.3 (7.7)	184.6 (52.0)	62 (2)	21 (1)	18 (1)	1.03 (0.29)

(continued)

Table 2 ***(continued)***

Sport, study	Combat characteristics	Match/round/ duration	Oxidative, kJ	Glycolytic, kJ	ATP-PCr, kJ	Total, kJ	Oxidative, %	Glycolytic, %	ATP-PCr, %	Metabolic power, kW
Taekwondo										
Campos et al[35]	Work-to-rest ratio was not reported but was calculated based on the total energy expenditure and metabolic power. Male athletes.	Round 1	98 (15)	11 (4)	49 (11)	158 (17)	62 (6)	7 (2)	31 (7)	1.24 (0.14)
		Round 2	127 (14)	7 (4)	49 (10)	183 (17)	70 (6)	4 (2)	26 (5)	1.43 (0.19)
		Round 3	134 (18)	6 (5)	63 (32)	203 (29)	67 (12)	3 (3)	30 (12)	1.54 (0.22)
		Mean	120 (22)	8 (5)	54 (21)	181 (28)	66 (6)	4 (2)	30 (6)	1.40 (0.22)
Lopes-Silva et al[36]	Supplementation study. Only the placebo condition was used in the present table. No work-to-rest ratio was reported. Total time included the between-rounds intervals. Male athletes.	Round 1	97.1 (7.8)	13.3 (6.9)	43.4 (7.4)	154.2 (17.0)	63 (5)	9 (5)	27 (3)	1.28 (0.01)
		Round 2	116.8 (15.2)	7.5 (5.5)	42.6 (8.7)	163.9 (27.1)	70 (3)	4 (3)	26 (2)	1.39 (0.04)
		Round 3	109.8 (16.4)	5.8 (3.3)	54.7 (24.2)	167.6 (28.3)	64 (9)	3 (2)	33 (2)	1.42 (0.09)
Lopes-Silva et al[37]	Supplementation study. Only the placebo condition was used in the present table. Work-to-rest ratio = 2.3:1. Therefore, 52.2 s was added to the valid combat time of each round plus intervals between rounds. Male athletes.	Round 1	109.9 (27.8)	8.6 (3.2)	39.8 (11.0)	155.2 (38.5)	71.3 (6.6)	5.5 (1.9)	24.8 (3.8)	0.92 (0.07)
		Round 2	117.0 (15.0)	6.4 (1.9)	40.9 (11.8)	164.7 (21.7)	71.7 (3.9)	3.8 (0.6)	24.5 (3.7)	0.95 (0.04)
		Round 3	120.3 (18.0)	5.7 (3.5)	49.5 (13.7)	177.8 (29.9)	67.9 (3.8)	4.2 (2.3)	28.4 (5.1)	1.02 (0.04)
		Mean	117.7 (17.5)	7.4 (1.1)	43.4 (9.9)	165.7 (28.0)	58.4 (7.1)	4.5 (0.9)	25.9 (2.0)	0.78 (0.05)

Abbreviations: ATP-PCr, adenosine triphosphate and phosphocreatine; NE, not estimated; NR, not reported. Note: Values are represented as mean (SD).

[a] All matches grouped; differences between the energy systems in each individual study were omitted; when the energy-system contribution percentages were not provided, they were calculated based on the absolute values reported; when metabolic power was not reported by the authors, the calculation involved the total energy expenditure provided by the authors divided by an estimate of total match time (valid combat time plus pauses and intervals).

Table 3 Variables and Physiological Parameters for HIIT Prescription and Its Main Goals

Variable	HIIT long intervals	HIIT short intervals	Repeated-sprint training	Sprint interval training
Effort duration	1–3 min	15–60 s	3–8 s	20–30 s
Effort intensity	90–100% iVO_2max	100–120% iVO_2max	120–170% iVO_2max	All-out (~120–180% iVO_2max)
Pause duration	<2 min (if passive) ~4 min (if active)	<15 s (if passive) 15–60 s (if active)	20–60 s	2–4 min
Pause intensity	Passive Active (40–60% iVO_2max)	Passive Active (30–40% iVO_2max)	Passive Active (30–40% iVO_2max)	Passive Active (30–40% iVO_2max)
Sets	4–10	10–20	10–20	4–8
Effort:pause ratio	1:1–4:1	1:1–2:1	>1:8	>1:8
Main goal	Metabolic (oxidative plus anaerobic systems) development	Metabolic (isolated or combined oxidative and anaerobic systems) and neuromuscular development	Metabolic (oxidative plus anaerobic systems or peripheral oxidative plus anaerobic systems) and neuromuscular development	Metabolic (peripheral oxidative plus anaerobic systems) and neuromuscular development

Abbreviations: HIIT, high-intensity interval training; iVO_2max, intensity associated with maximal oxygen consumption. Note: Based on Buchheit and Laursen.[16,17]

Table 4 Parameters Used as a Reference for Prescribing Different Types of HIIT for Hypothetical Olympic Combat-Sport Athletes

Variable	HIIT long intervals	HIIT short intervals	Repeated-sprint training	Sprint interval training
Combat sport	Taekwondo	Karate	Boxing	Wrestling
Tests executed and results	Taekwondo-specific aerobic power test[44]: FK_{peak} = 34 rep·min^{-1}; FKHRDP = 19 rep·min^{-1}	Taekwondo-specific aerobic power test[44]: FK_{peak} = 32 rep·min^{-1} and FSKT 10 s[49,50] = 20 kicks (120 rep·min^{-1}), both adapted to *mawashi-geri chudan*[a]; ASR = 88 rep·min^{-1}	No tests; training described by Kamandulis et al[43]; 3 rounds of 14 × 3-s all-out punching-bag exercise	No tests. Suples dummy throwing
Effort duration	1 min	15 s	3 s	30 s
Effort intensity	90% of MAS (31 rep·min^{-1}) or delta 75% FK_{peak} and FKHRDP = 30 rep·min^{-1}	Delta 20% of ASR (50 rep·min^{-1}; ~12 kicks in 15 s)	All-out	All-out
Pause duration	1 min	15 s	10 s between sets and 1 min between rounds	4 min
Pause intensity	40% FK_{peak} (12 rep·min^{-1})	Passive recovery	Passive recovery	Active recovery and self-selected jogging
Sets	Up to exhaustion	Up to exhaustion	3 rounds of 14 sets	4
Effort:pause ratio	1:1	1:1	1:4	1:8

Abbreviations: ASR, anaerobic speed reserve; FKHRDP, frequency of kicks at the heart-rate deflection point; FK_{peak}, peak of frequency of kicks; FSKT, frequency speed of kick test (10-s all-out test); HIIT, high-intensity interval training; MAS, maximal aerobic speed; rep, repetitions.
[a] Roundhouse-kick technique directed to the trunk level.

verify the performance and physiological responses to individualized running velocities in supramaximal sprints. They revealed that the prescription based on the delta intervals using the anaerobic speed reserve resulted in lower variation in time limit (41%–55% less variation) and blood lactate (51%–53% less variation) compared with the prescription based on supramaximal loads (ie, using solely the maximal aerobic speed). Therefore, to achieve a more individualized prescription, it is recommended to utilize the anaerobic speed reserve using combat sports-specific exercises to prescribe the HIIT short intervals and repeated sprint training.

For the sprint interval training protocol, no previous tests are needed for its prescription because it is based on all-out efforts. However, the strength and conditioning professionals should consider that this protocol is not similar to the time–motion analysis of combat sports matches (Table 1) and should be used only when a high-metabolic stress is desired.

Another approach frequently used in combat sports is to organize the HIIT protocol using time–motion structure of official matches as the reference,[41–43] which not always can be easily classified in one of the 4 categories proposed by Buchheit and Laursen.[16]

HIIT Prescription for Combat Sports

Combat sports athletes execute many different exercises in their training routine, including general and combat sport-specific exercises.[14] However, most of the technique skill development as well as combat sport-specific training is conducted using sets interspersing high-intensity actions with low-intensity recovery or pauses. Specifically concerning the physical training, different combinations of these exercises, varying intensity and duration of work and rest periods, are elaborated to develop strength, muscle power, speed, strength endurance, aerobic and anaerobic power, and capacity. Therefore, typical combat sports tasks involving either grappling or striking techniques were used in this article as an exercise mode to exemplify HIIT protocols for combat sports athletes. Examples of the 4 categories of HIIT proposed by Buchheit and Laursen[16] adapted for combat sports-specific actions are presented below.

The use of mechanical or physiological parameters is considered the most practical approach to prescribe the HIIT. In this way, a submaximal (eg, maximal lactate steady state, critical power or velocity, anaerobic threshold, ventilatory thresholds, respiratory compensation point, lactate minimum), a maximal (eg, maximal oxygen uptake) and a supramaximal (eg, maximal sprint speed or peak power) physiological and/or mechanical parameters have been suggested to provide the intensity markers needed for individualized prescription.[16,17] For combat sports, different submaximal,[44–46] maximal,[46–48] and supramaximal[49,50] tests using throwing, kicking, and punching techniques are available and can be used to establish the physiological or mechanical parameters needed to prescribe the HIIT. Briefly, it is possible to determine the 3 parameters (ie, submaximal, maximal, and supramaximal) for judo and taekwondo, whereas 2 of these parameters can be determined for fencing, and the tests used for taekwondo can be easily adapted for karate. The reading of a critical literature review of these tests is recommended to facilitate the decision making concerning the use of a combat sport-specific test.[39]

Table 4 presents a synthesis of the proposed protocols for hypothetical Olympic combat sports athletes, using the classification proposed by Buchheit and Laursen.[16]

In addition to the protocols described previously, strength and conditioning professionals can also create combat sport-specific protocols considering the time–motion data presented in Table 1.

Practical Applications

Coaches and strength and conditioning professionals should consider the combat sport athletes' needs based on the athletes' physical fitness, combat sport time structure, and energy demands, to select the proper HIIT protocol to achieve the athletes' specific goals. The specificity and individualization principles are more likely to be reached if combat sport-specific tests are used to prescribe HIIT sessions and if the intensity parameters (submaximal, maximal, and supramaximal) are used to establish these protocols characteristics.

Conclusions

The decision making concerning the use of a given HIIT protocol depends on the characteristics of each combat sports. In this review, 2 main aspects were considered: the time–motion and the energy systems contributions. Therefore, based on these aspects, different HIIT protocols were suggested to combat sports athletes using sport-specific tests to allow a better individualization of the training loads. Other protocols can be elaborated to promote specific training adaptations considered necessary for a given athlete. In addition, future investigations need to be conducted to verify the effectiveness of different HIIT protocols on distinct physical capacities and on combat sport-specific performance.

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