Judo Competition Demands

Executive Summary

Work:Rest ratios & make up of work blocks

Initial research reported Work:Rest ratios consistently in the region of 2-3:1, typically 20-30s work 5-10s rest (worst case 1 min?). Some studies (simulations) have reported 1:1 (13:13s), others ~3.7:1 (23.9 – 28.5 s combat, 4.0 – 8.8 s rest) from combats in international ranking events, with differences between weight classes and genders.

~ 12 work/rest blocks per fight

Broadly in one study, time spent in standing to ground work has been shown to be as low 3:1 (Female U52 kg WC) and as high as ~7:1 Discrepancies on the make-up of each block due to classification and reliability of testers – e.g. work block divided into kumi kata (32%), attack/defend (26%), transition/ne waza (19%) and matte (23%) in one study, compared to preparation (12.6%), grip (51.3%), technique (4%), ne waza (14.3%) and matte (18%)

Grip struggle: No difference in max hand grip strength between levels, however, hand grip endurance potentially more important than max strength. Most of a match spent in grip disputes (kumi-kata) - 15-20 times per bout consuming 51 ± 11% of the (work) time (1/3rd of total time), requiring high level of upper-body strength endurance

Internal demands: Lactic acid concentrations found after bouts between experienced judo athletes range from 13 - 18 mmol·L^{-1}, correlation between the rate of perceived exertion and maximal [La] during competition.

Heart rates during bouts in simulated contests recorded at between 180 and 185 b·min^{-1} and consistently reported at >85% during actual and simulated combat.

In simulation fights peak [La] was higher after the first combat compared to the second, third and fourth combat. Suggesting decreased anaerobic and increased aerobic contributions

Aerobic: Research has indicated that the aerobic profile of judo athletes may be important during several situations: (a) in the final moments of a combat; (b) when a high number of matches are performed in the same competition; and (c) during the recovery process between the matches.

VO2 max quoted in elite judokas comparable with team sport athletes

UB test scores seem to distinguish levels more than lower body for example UB Wingate scores ~81% of lower body scores in high level judokas

Additional thoughts: Worst Case Scenario for Judo? worst grip sequence, worst ground sequence etc. Worst overall sequence?

Title	Method	Results	Notes
Franchini et al (2013) Judo combat: time-motion analysis and physiology	Review paper. Varied subjects from Student to International competitors (1982-2012)	**Work rest ratio** is 2-3:1 (typically 20-30s, WCS ~1 min?), independently of gender, age or weight categories. Most combat time is spent in grip disputes ~50% of total work time or ~28% of total match, requiring high-levels of isometric and dynamic strength-endurance, especially from the forearms. Throwing techniques demand both lower & upper-body power development. **Lactate:** Simulations: 7.5 – 18.1 mmol·L^{-1} (across multiple and single matches) from juniors to international. ~3 mmol·L^{-1} lower than data from actual matches. Multiple matches lead to higher resting lactate (~3-4 x higher pre 3rd fight) however, lactate values at the end of matches decreases suggesting a decrease in anaerobic lactic contribution as the athletes perform consecutive matches. **Aerobic fitness** important in the last minutes of the match, extra-time or to increase recovery between matches.	No decrement in leg power seen across 4 matches, however hand grip strength decreased after 3rd & 4th Lactate: Female (lack of data) appears similar to male Weight class? Higher lactate in standing only vs ground only (1 study, 11.3 vs 7.7 mmol·L^{-1}) 10-fold increase in the probability of winning the match when athletes performed active recovery and opponents performed passive recovery. This could be attributed to a faster reaction time, movement initiation and movement times after active compared to passive recovery Gariod et al. (1995) reported that judo athletes with higher

			VO2max presented a faster PCr resynthesis compared to those with lower VO2max.
Sterkowicz-Przybycien et al (2017) Sex and Weight Category Differences in Time-Motion Analysis of Elite Judo Athletes: Implications for Assessment and Training	A total of 1,411 judo matches contested by 147 senior level men (21 from each weight category). 98 senior level women (14 from each weight category) who qualified for the 2012 Olympic Games were analysed. Phase Definition For analysis grouped as follows: Extra lightweight (F1: -48 kg; M1: -60 kg) Lightweight (F2: -52, -57, -63 kg; M2: -66, -73, -81 kg) Middleweight (F3: -70, -78 kg; M3: -90, -100 kg) Heavyweight (F4: +78 kg; M4: +100 kg).	There are large differences by weight category and sex divisions on phases of combat in elite judo athletes. The accumulated total combat time appeared to be similar between men and women in corresponding weight groups except for the middleweight (F3/M3) category, whereas the accumulated pause time differed in only the heavyweight (F4/M4) category. Sex-specific work-to-rest ratios, developed from the differences in gripping and attack values, should be considered when structuring conditioning drills. The lightest and heaviest competitors displayed unique characteristics, compared with athletes in the other weight categories. Male middleweight athletes must physically prepare for longer combat phase and sub-phases than female middleweight athletes. Results – Total match time in each phase Results – Average time of each phase	

Challis et al (2015) A Time-Motion Analysis of Lightweight Women's Judo in the 2010 World Championships	Light weight (U48, 52 & 57 kg) women's contests (143) from 2010 World Championships	A total of 1756 hajime to matte blocks (work), 1422 matte to hajime blocks (rest), 1786 kumi-kata sequences (gripping sequences), and 516 ne-waza sequences (ground work). The results suggest the time spent in hajime to matte (work) and in matte to hajime (rest) are similar to those seen in other studies Bout duration 317 s (5 mins 17 s) Ne-waza/transition, although not as frequent (3.6) as other KPIs has a long duration (15.4 s) and therefore its contribution to the contest should not be underestimated. Work, Rest, Gripping, Att/Def, Ground Work FREQUENCY Work, Rest, Gripping, Att/Def, Ground Work TIME	
Hernández-García et al (2009) Physiological Requirements of Judo Combat	11 national and/or international level judokas. 2-3 simulations (5 mins)	Average bout 375 ± 30 s Avg HR 180 ± 8 beats·m^{-1} Max HR 188 ± 7 beats·m^{-1} Lactate 8.4 mmol·L^{-1} Standing:Ground Work ~7:1 Work:Rest ~4:1 Work, Rest Time & Frequency Results	
Challis (Poster Presentation) A Temporal Analysis of the u48kg Women's Judo in the 2010 World Championships	48 fights from the Women's U48 kg (2010 WCs)	Average contest duration (inc rest blocks) 5.53 mins 12.3 Work:Rest blocks per fight Avg bout duration 28.7 s (12.3 s Rest) Work:Rest = 2.3:1 Each work block divided into kumi kata (32%), attack/defend (26%), transition/newaza (19%) and matte (23%) of the contest.	Different results for Grip time with this study suggesting 32% and Marcon et al suggesting 63.9% of each segment. Unknown why discrepancy is so large but could possibly be due to how

			the authors defined this section or possibly that the u48kg spend much less time in kumi kata.
Marcon et al (2010) Structural Analysis of Action and Time in Sports: Judo	10 Male Judokas (regional level black belt) evaluated for 3 combats each using new computer software. Broken down into 6 categories: 1 – Break 2 – Preparation (movement non contact) 3 – Grip 4 – Technique (executes tech or throw during standing combat) 5 – Fall 6 – Groundwork	Average of 11 sequences per combat (4 on ground) Combined for the 3 combats sequences were approx. - preparation was 12.6%, grip was 51.3%, technique was 4%, ne waza was 14.3% and matte was 18% of a segment Results – Time in Sequences Results – Percentage in Sequences	Inter rater reliability poor for all measures (apart from break time) Intra rater reliability acceptable (apart from technique and fall)
Bocioaca (2014) Technical and Tactical Optimization Factors in Judo	Analysed 150 Matches during World, European Championships & Olympics, from 2010-2012 for techniques used	Technical and tactical actions conducted in the fight (standing) Technical and tactical actions conducted in the fight (ground)	Romanian team scouting Language makes paper hard to follow
Bonitch-Gongora et al (2012) The Effect of Lactate Concentration on the Handgrip Strength During Judo Bouts	10 National & 2 Regional Championship medallists (all male). Simulated Judo contest 4 x 5 min bouts with 15 mins passive recovery. Handgrip test	Successive judo bouts significantly reduce the maximal isometric strength of both hands and may suggest that fatigue of each hand depends on different factors **Work:Rest** 13.95 ± 9.09 to 13.79 ± 9.47 seconds, mean number of attacks during each bout was 10.5 ± 4.1.	

	Immediately pre & post each bout, lactate taken at 1, 13 & 14 min post bout	Grip strength 575.9 ± 69.1 and 554.3 ± 74.2 N for the dominant and non-dominant hands (0.78 & 0.75 kg/kg). Similar to other studies of same level Lactate responses to each bout Handgrip scores pre/post each bout Inverse relationship between the max handgrip strength (post bouts) & post effort lactic acid concentrations	
Ryszard et al (2014) The Course of the Judo Fight in the Heaviest Category (+100kg) Seen from the Perspective of Attacks in the Standing Position, Based on the Olympic Games in London 2012	All fights from the +100kg class during London 2012 Games. 32 competitors, 34 fights The analysis concerned all the attacks observed: 1 – awarding points: attacks backwards, attacks forwards, situational attacks. 2 – not awarding points: attacks backwards, attacks forwards, situational attacks. 3 – not awarding points: attacks backwards attacks forwards, situational attacks that directly resulted in a penalty and gave points to the attacker.	There were observed different trends in the number of attacks: decrease in the number of attacks backwards, increase in the number of attacks forwards and in the effectiveness of attack, which resulted in the changing course of the fight. 1st min of fight highest no. of attacks with lowest efficiency 3rd min decrease in no. of attacks (but increase in efficiency) then increase in no. & efficiency in 4th min Backwards attacks dominant in early minutes, in last minute and added time forwards attacks dominate Results – Attacks and points distribution Results – Minute breakdown of attacks & points	The actions on the ground (ne waza) due to the small number (5 shares) were not analysed

	4 – time for points awarding attack, or penalty by the opponent.		
Calmet et al (2010) Modelling of Grasps in Judo Contests	Winners of 35 bouts – 9 beginners (1 min bouts), 16 intermediate (3 min bouts), 10 international (5 min bouts)	Grip approach differed between levels. Grip time is longer for beginners, who spend most of the time with grip contact and trying to apply a technique. Intermediate level judokas perform only one process, from reaching from afar to close-up contact, while expert level expert judokas spend more time in grip contest (trying to grip the opponent without being gripped) and less time with both contact grips. Additionally, the expert group spends less time between the grip and the technique execution. These results can be used to direct the technical and tactical training in order to improve grip contest. Time Spent in Different Behaviours	
Sterkowicz et al Techniques Frequently Used During London Olympic Judo Tournaments: A Biomechanical Approach	Analysed 359 throws and 77 grappling techniques scored by male and female athletes in Olympic Judo Tournament (London 2012)	Difference found between frequencies of variable arm of physical lever technique scored by males (27.09%) and females (16.67%) as compared to the rest/inconclusively techniques counts. Differences between male extra lightweight & heavyweight on frequency of the techniques used with maximum arm or variable arm of physical lever and a couple of forces applied by trunk and legs. In females, a tendency for higher frequency of techniques that used couple of forces applied by arm or arms and leg was observed in extra lightweight compared to the heavy weight. Results – Frequency of throw techniques Results – Frequency of grapple techniques Results – Number of penalties	Poor English hard to follow

Franchini et al (2011) Physiological Profiles of Elite Judo Athletes	Review paper: Varied subjects from Student to International competitors	Body Composition Males: 7 – 14% Females: 15 – 22% (Equation dependent) Isometric Grip Strength: Max values remain similar to studies in 1960's & do not appear to distinguish between levels (only between cadet and senior). Scores reported would only be considered 'good' compared to US population data. Grip endurance may be a more relevant measure however no research on this. Upper body Wingate: In 90th centile of population. Females ~70% of Male scores. Better performance indicator than lower body Wingate. Upto 81% of LB Males: MPO 5.4 – 8.8 W·kg^{-1} PPO 7.6 – 11.3 W·kg^{-1} Females: MPO 3.8 – 4.5 W·kg^{-1} PPO 5.5 – 5.8 W·kg^{-1} Lower Body Wingate: Males: MPO 5.4 – 12.0 W·kg^{-1} PPO 9.6 – 16.2 W·kg^{-1} Females: MPO 4.3 – 9.6 W·kg^{-1} PPO 8.9 – 10.7 W·kg^{-1} Aerobic Capacity: Males 50 – 60 ml·kg·min^{-1} Females 40 – 50 ml·kg·min^{-1}	Limited data on Female athletes.

Bonitch-Domínguez et al (2010) Changes in Peak Leg Power Induced by successive Judo Bouts and their Relationship to Lactate Production	9 National & 2 Regional Championship medallists (all male). Simulated Judo contest 4 x 5 min bouts with 15 mins passive recovery. Optimal load for squat assessed and this load used to assess power pre and post each bout Lactate was taken 1,3,5 & 14 min post bout	A bout, or a succession of bouts, in a simulated judo contest results in a high demand on the lactic anaerobic metabolism, which does not, however, affect the capacity to generate high leg power in the movement employed in this study. Lactate responses to simulated competition Power response to simulated competition	Why use squat to assess power? Jump?! LPT used not Force Plate
Franchini et al (2011) Energy System Contributions to the Special Judo Fitness Test	14 male black belt judokas (19 ± 2.4 yrs). Tested VO2 max (graded treadmill test), 30s Wingate & the Special Judo Fitness Test - divided in three periods (A = 15 s; B and C = 30 s) with 10 s intervals between them. Each partner was positioned 6 m apart and the participant was required to run to each partner and then throw them as many times as possible using the ippon-seoi-nage technique	Reported a higher alactic contribution (42.3 ± 5.9%) compared with both aerobic (28.2 ± 2.9%) and lactic contributions (29.5 ± 6.2%) during the SJFT VO2, WAnT & SJFT results	Throwing only test no grappling. Likely would change the energy demands? This cohort scored poorly on the SJFT and WAnT

Franchini et al (2013) Specificity of Performance Adaptations to a Periodised Judo Training Program	10 Male Judokas (Brown or Black belt, state level) Tested on: body comp, anaerobic power & capacity (UB & LB Wingate), LB power (CMJ Ht), aerobic power (UB & LB Incremental tests), max strength (1RM) & endurance (reps @ 70% 1RM), Grip strength, Grip endurance – Judogi wrapped around a bar. (Isometric chin up hold & Dynamic chin ups) Special Judo Fitness Test across training blocks from prep to competition (18 weeks) Training Periodisation	↑ UB anaerobic power (15%) & capacity (17%) ↑ LB anaerobic power (13%) ↑ Isometric (39%) & dynamic grip strength endurance (57%) ↑ UB aerobic power (8%) ↑ row 1RM (8%) ↓ LB aerobic power (-11%). Body comp, judo specific performance, handgrip strength, bench-press 1RM, row and bench-press no. of reps @ 70% 1RM, and lower-body muscle power did not improve Table of Results	CMJ Ht not sensitive enough measure?
Degoutte et al (2003) Energy Demands During a Judo Match and Recovery	16 Male interregional Judokas (2^{nd} – 3^{rd} Dan black belt). Venous blood samples collected Pre, 3 mins post, 1 hr & 24 hour post Judo simulation match and analysed for metabolites of the oxypurine cascade, lipolytic	Athletes followed a low carbohydrate diet. Lactate increased to 12.3 mmol·L^{-1} at the end of the match. Post-match increase in ammonia, urea, hypoxanthine, and xanthine concentrations with no change in uric acid. An increase in triglycerides, free fatty acids, glycerol, and HDL-C also noted. All these variables returned to baseline within 24 hours except for uric acid and urea, which had increased substantially one hour after the end of the match and remained elevated the following morning.	Is 50% Energy from CHO low? VO2 max = 55 ml·kg·min^{-1} Max HR = 198 beats·min^{-1} Match avg HR = 182 beats·min^{-1}

	activity, and glycolytic pathway.	Blood Results	
Torres-Luque et al (2016) Physical and Physiological Characteristics of Judo Athletes: An Update	Review Paper: Varied subjects from Recreational to International competitors	**Body Comp:** BF% decreased as competition level increased. Elite Females ~10% higher than Males Age categories - in females, cadet category, 19.5% body fat, junior category, 24.0% body fat & in senior category, 19.9%; in males, of the cadet category, 12.1% body fat, in the junior category, 10.6% body fat, and the senior category, 8% body fat **Aerobic Capacity:** Male judokas had higher VO2max values (44 – 65 ml·kg·min^{-1}) than females (from 43 – 53 ml·kg·min^{-1}). By weight categories, values from 39 – 57 ml·kg·min^{-1} were reported for lightweight, from 42 – 59 ml·kg·min^{-1} for medium weight and from 42 – 59.5 ml·kg·min^{-1} for the heavy weight category.	
Fitness and Anthropometric Profiles of International vs. National Judo Medalists in Half-Heavyweight Category	-100 kg Judokas. 5 Elite (won ≥1 medal at European Judo Championship, World or European Judo Cup during the previous 2 years). 5 Sub-elite won ≥1 medal but only in national competitions (Serbia or Bosnia and Herzegovina). Fitness tests: peak torques for thigh and shoulder	Elite scored significantly better on forearm and upper-arm circumferences, peak torques (knee ext, shoulder ext rot), pull-ups, bench press (max & reps @100kg), deadlift, deep squat (reps @100kg), VO2max, Power, and Tokui Waza tests Anthropometry Results Isokinetic Results Fitness Test Results	Testing speed 60^{o}·s^{-1} for Isok High Jump?

	muscles, handgrip strength, high and long jumps, medicine ball throw, pull-ups, deadlift, bench press, deep squat, VO2max, Max Power (8s Wingate avg power), and Tokui Waza tests		
James et al (2016) Towards a Determination of the Physiological Characteristics Distinguishing Successful Mixed Martial Arts Athletes: A Systematic Review of Combat Sport Literature	Review of Combat Sports	There appear to be differing physiological profiles between more successful grappling and striking combat sport athletes. Grappling sports high force (max strength) compared to lighter load higher velocity for striking sports. Anaerobic capabilities distinguish higher for lower level combat athletes. Longer term anaerobic efforts seem to define grappling athletes Proposed F-V Profile MMA (Strike vs Grapple) Proposed Physiological Profile (Strike vs Grapple)	
Franchini et al (2014) The Physiology of Judo-Specific Training Modalities	Review Paper	Uchi-komi and nage-komi exercises can be used for metabolic training, with continuous steady-state or technique repetition every 10–15 seconds being useful for aerobic fitness development, whereas all-out intermittent protocols are useful especially for anaerobic development but may elicit aerobic improvements as well. Techniques involving trunk rotation and accentuated knee flexion (e.g. seoi-nage) are more physically demanding than frontal attacks (e.g.o-uchi-gari).	Some data from late 80's relevance?

		Longer randori sessions with lower intensity combat sessions and shorter rest intervals are more appropriate or improving aerobic fitness. However, to improve anaerobic capacity, combat sessions should be more intense, shorter in duration, and interspersed by longer intervals. Changes in immune function and selected blood amino acids and markers of muscle damage are also important to be monitored throughout the season as they may provide early evidence of overtraining.	

Table 1. Competitive model to technical and tactical actions conducted in the fight standing.

No	The name of the technique, according to the international classification	The total number of attack	Number of actions performe on the left side	Number of actions performe on the right side	Effective percentage of shares (with score)
1	SEOI-NAGE	216	129	87	20
2	UCHI- MATA	170	102	68	16
3	TAI-OTOSHI	40	22	18	3.7
4	O-UCHI-GARI	74	44	30	7
5	KO-UCHI-GARI	48	37	11	4.4
6	HARAI-GOSHI	47	25	22	4
7	O-SOTO-GARI	32	18	14	3
8	KO-SOTO-GARI	30	17	13	2.77
9	YOKO-OTOSHI	21	12	9	2
10	SEOI-OTOSHI	26	14	12	2.4
11	TANI-OTOSHI	23	13	10	2.1
12	KATA-GURUMA	31	17	14	2.87
13	DE-ASHI-HARAI	32	17	15	3
14	SASAE-TSURI	8	3	5	0.74
15	MOROTE-GARI	30	16	14	2.77
16	TOMOE-NAGE	43	25	18	4
17	SUMI-GAESHI	35	15	20	3.24
18	O-GOSHI	41	24	17	2.87
19	URA-NAGE	14	10	4	2
20	SUMI-OTOSHI	20	5	15	2
21	KIBISU-GAESHI	18	9	9	1.66
22	USHIRO-GOSHI	30	17	13	2.77
23	SODE-TSURI-KOMI-GOSHI	25	15	10	2.31
24	OTHER	26	16	10	2.4
25	TOTAL	1080	622	458	100

Table 2. The technical competitive actions in the fight to the ground.

No.	The name of the technique, according to the international classification	The total number of attack	Effective percentage of shares (with score)
1	KESA - GATAME	49	18
2	KATA - GATAME	38	14
3	KAMI - SHIHO - GATAME	21	7.7
4	YOKO - SHIHO -GATAME	12	4.4
5	TATE – SHIHO - GATAME	8	3
6	NAMI - JUJI - JIME	15	5.5
7	GYAKU - JUJI - JIME	9	3.3
8	KATA - JUJI - JIME	12	4.4
9	OKURI - ERI - JIME	36	13.7
10	TSUKIKOMI - JIME	25	9
11	UDE - HISHIGI - JUJI - GATAME	32	11.5
12	UDE - HISHIGI - WAKI - GATAME	5	2.5
13	UDE - HISHIGI - SANKAKU - GATAME	3	1
25	OTHER	5	2
26	TOTAL	270	100

TABLE 3. Blood lactate concentration by bout.*

Bout no.	Lacmax (mmol·L^{-1})	Lac14 (mmol·L^{-1})	%Lac clear
1	18.12 ± 4.40†	11.37 ± 3.92†	37.74 ± 15.51
2	16.95 ± 3.58†	12.73 ± 4.48†	26.89 ± 16.19
3	15.27 ± 4.47	10.03 ± 4.06	36.27 ± 13.08
4	14.58 ± 3.57	8.41 ± 2.71	42.54 ± 9.12
P	0.000	0.010	$p > 0.05$

*Lacmax = maximal blood lactate concentration; Lac14 = maximal blood lactate concentration 14 minutes after the bouts.

†Difference with respect to bout 4.

TABLE 2. Analysis of the maximal isometric handgrip strength for both hands during the bouts.*

	MIS-B (N)			MIS-A (N)		
Bout no.	Dominant	Nondominant	*P*1	Dominant	Nondominant	*P*1
1	575.85 ± 69.14	554.26 ± 74.20	0.147	502.52 ± 57.03	495.89 ± 63.90	0.590
2	525.24 ± 76.84	517.97 ± 73.45	0.596	489.76 ± 71.84	480.28 ± 67.50	0.494
3	528.35 ± 75.89†	494.83 ± 68.03†	**0.043**	484.04 ± 88.22	477.26 ± 62.47	0.735
4	527.29 ± 92.38‡	490.58 ± 75.70‡	**0.022**	489.27 ± 94.91	479.87 ± 59.78	0.652
P	**0.002**	**0.000**		0.529	0.216	

*MIS-B = Amaximal isometric strength before the bout; MIS-A = maximal isometric strength after the bout; *P* = overall effect of the bout; *P*1 = statistical difference between the dominant and nondominant hand for each measurement.

†Difference between bouts 1 and 3 ($p < 0.05$).

‡Difference between bouts 1 and 4 ($p < 0.05$).

Table IV. The effect of successive bouts on lactate clearance between bouts (mean ± s).

	Bout				
Variable	1	2	3	4	*P*-value
Maximal blood lactate concentration ($mmol \cdot l^{-1}$)	14.6 ± 4.0	14.9 ± 4.0	13.9 ± 2.8	12.6 ± 3.5	$P < 0.05$
Blood lactate concentration at minute 14 ($mmol \cdot l^{-1}$)	9.2 ± 3.1	8.7 ± 3.2	8.1 ± 2.4	7.5 ± 2.5	$P > 0.05$
% lactate clearance	37.2 ± 11.3	41.9 ± 9.2	42.5 ± 6.7	40.9 ± 7.7	$P > 0.05$

Table III. The effect of successive bouts on the power, force, and velocity before and after each bout.

	Bouts								
	1		2		3		4		
	before	*after*	*before*	*after*	*before*	*after*	*before*	*after*	*P*-value
Peak power ($W \cdot kg^{-1}$)	25.0 ± 3.5	25.3 ± 3.6	25.4 ± 2.7	23.3 ± 4.7	24.5 ± 3.5	24.6 ± 3.7	24.6 ± 3.1	25.5 ± 3.9	$P > 0.05^{a,b,c}$
Peak power (W)	1969.7 ± 439.2	1976.6 ± 366.1	1993.8 ± 342.4	1821.2 ± 453.4	1917.9 ± 345.9	1919.8 ± 357.6	1917.8 ± 275.9	2013.0 ± 453.9	$P > 0.05^{a,b,c}$
Force (N)	1739.4 ± 404.4	1756.8 ± 370.7	1762.2 ± 402.3	1699. 9 ± 357.4	1733.8 ± 370.6	1751.7 ± 387.1	1731.7 ± 349.0	1773.1 ± 398.8	$P > 0.05^{a,b,c}$
Velocity ($m \cdot s^{-1}$)	1.14 ± 0.11	1.14 ± 0.13	1.15 ± 0.12	1.07 ± 0.16	1.12 ± 0.13	1.12 ± 0.15	1.12 ± 0.13	1.14 ± 0.14	$P > 0.05^{a,b,c}$

[a]Combat main effect (bout number 1 to 4). [b]Time of measurement main effect (before/after). [c]Interaction between time (before/after) and bout.

Table 1 Maximal oxygen consumption (VO_2max) during the treadmill test, peak and mean power during the Wingate test, and performance and energy system contributions to the Special Judo Fitness Test.

Variable	Mean ± *SD*
Treadmill Test	
VO_2max (mL·kg^{-1}·min^{-1})	56.42 ± 3.61
Wingate Test	
Peak power (W·kg^{-1})	11.65 ± 2.89
Mean power (W·kg^{-1})	10.03 ± 0.20
Special Judo Fitness Test	
Number of throws during A	6 ± 0
Number of throws during B	10 ± 1
Number of throws during C	9 ± 1
Total number of throws	26 ± 2
HR immediately after (beats·min^{-1})	196 ± 12
HR 1 min after the test (beats·min^{-1})	169 ± 9
Index (beats·min^{-1}·throw^{-1})	14.37 ± 1.33
Alactic contribution	
Absolute (kJ)***	86.8 ± 23.6
Relative (%)†††	42.3 ± 5.9
Lactic contribution	
Absolute (kJ)	58.9 ± 12.1
Relative (%)	29.5 ± 6.2
Aerobic contribution	
Absolute (kJ)	57.1 ± 11.3
Relative (%)	28.2 ± 2.9
Total Energy Expenditure (kJ)	202.8 ± 35.1

***Different from lactic and aerobic energy systems ($P < .001$).
†††Different from lactic and aerobic energy systems ($P < .001$).

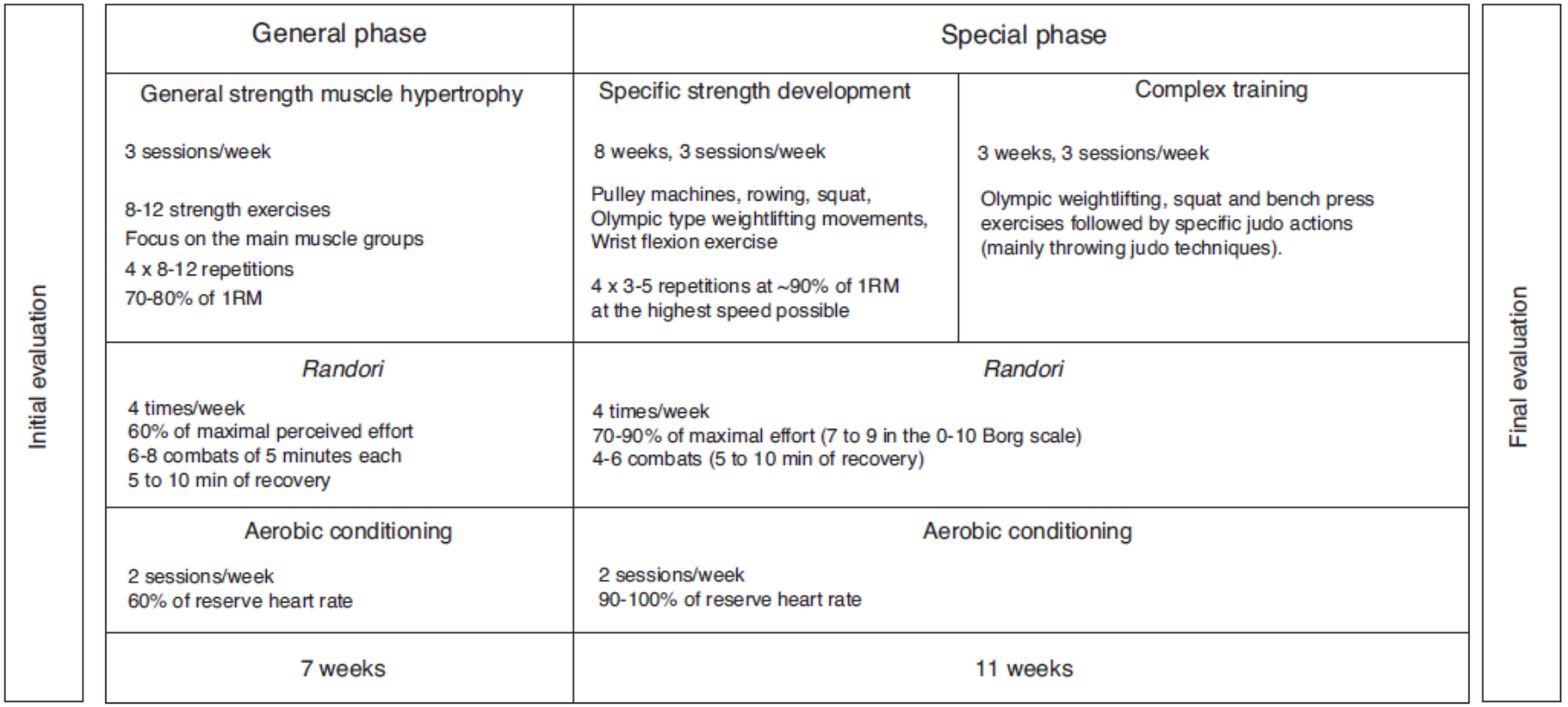

Fig. 1. Schematic representation of the training phases and periods of evaluation.

Table 1
Maximal isometric handgrip (kgf), one repetition maximum (1RM) in row and bench press (kg), judogi chin up repetitions and time of suspension (s), and number of repetitions at 70% 1RM in row and bench press exercises before and after periodization training cycle of state level male judo athletes ($n = 10$).

	Before	After
Right handgrip isometric strength (kgf)	61 ± 13	60 ± 13
Left handgrip isometric strength (kgf)	54 ± 12	55 ± 10
Bench press 1RM (kg)	88 ± 24	91 ± 23
Row 1RM (kg)	85 ± 23	92 ± 26*
Bench press at 70% 1RM (rep)	10 ± 7	13 ± 5
Row at 70% 1RM (rep)	17 ± 4	13 ± 3
Isometric chin up judogi (s)	31 ± 17	43 ± 15*
Chin up judogi (rep)	7 ± 5	11 ± 5*

* Significant difference between moments ($p < 0.05$); values are mean ± standard deviation.

Table 2
Number of throws (during sets A, B, C, and total), heart rate after and 1 min after the Special Judo Fitness Test, and index before and after periodization training cycle of state level male judo athletes (n = 10).

	Before	After
Throws set A (15 s)	6 ± 0	6 ± 1
Throws set B (30 s)	11 ± 0	11 ± 1
Throws set C (30 s)	10 ± 1	9 ± 1
Total throws	28 ± 1	26 ± 1
Heart rate after (bpm)	197 ± 6	190 ± 8
Heart rate 1 min after (bpm)	178 ± 9	171 ± 9
Index	13.66 ± 1.04	14.03 ± 1.15

Values are mean ± standard deviation.

Table 4 Nutritional assessment of the daily dietary intake of the judo athletes

		FRDA
Total energy intake (MJday)	13.4 (0.8)	12.5–14.6
Daily energy expenditure (MJ/day) with no training	7.6 (0.3)	
Daily sport activity (MJ/day)	7.3 (0.5)	
Daily energy expenditure (MJ/day)	13.9 (0.6)	
Protein (%)	15.3 (2.0)	15
Fat (%)	33.0 (4.3)	<30
Carbohydrate (%)	50.9 (4.5)	60
Total protein (g/day)	103.4 (26.0)	81
Total fat (g/day)	100.5 (31.4)	100
Carbohydrate (g/day)	333.2 (91.8)	450
Water (g)	4045.0 (350)	3500
Saturated fat (g)	38.8 (2.8)	1/3 of total fat
Monounsaturated fat (g)	31.6 (3.9)	1/3 of total fat
Polyunsaturated fat (g)	9.3 (1.9)	1/3 of total fat

Values are mean (SEM). For comparison, the French Recommended Dietary Allowances (FRDA) for sportsmen[9] are shown.

Table 2 Effect of the judo match on serum lipid and lipoprotein levels

	TC (mmol/l)	TG (mmol/l)	FFA (mmol/l)	Glycerol (μmol/l)	LDL-C (mmol/l)	HDL-C (mmol/l)
Resting values (T_1)	4.50 (0.2)	0.86 (0.08)	0.40 (0.03)	74.0 (4.44)	2.9 (0.10	1.23 (0.06)
3 min after match (T_2)	4.76 (0.1)*	1.15 (0.1)*	0.57 (0.05)*	148.4 (15.8)*	2.9 (0.1)	1.33 (0.08)*
60 min after match (T_3)	4.5 (0.2)	0.75 (0.07)	0.54 (0.03)*	117.0 (13.2)*	2.88 (0.2)	1.26 (0.06)
24 h after match (T_4)	4.22 (0.2)**	0.88 (0.1)	0.50 (0.04)	85.3 (7.0)	2.73 (0.2)	1.12 (0.06)**
Norm	3–6	0.5–1.6	0.1–0.5	50–100	2.9–4	0.75–1.6

Data are mean (SEM), n=16. For comparison, reference ranges for adults are listed (Norm).
Significantly different from resting values: *p<0.05; **p<0.01.
TC, Total cholesterol; TG, triglycerides; FFA, free fatty acids; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol.

Table 3 Effect of the judo match on plasma concentrations of lactate, ammonia, hypoxanthine, xanthine, uric acid, urea, and creatinine at rest and after the match

	Ammonia (μmol/l)	Hypoxanthine (μmol/l)	Xanthine (μmol/l)	Uric acid (mmol/l)	Urea (mmol/l)	Creatinine (mmol/l)	Lactate (mmol/l)
Resting values (T_1)	62.3 (4.3)	14.4 (1.0)	4.6 (1.0)	324.5 (10.8)	5.2 (0.2)	101.6 (1.5)	1.2 (0.1)
3 min after match (T_2)	141.5 (12.6)**	15..8 (1.1)*	16.0 (2.9)*	327.0 (11.0)	5.6 (0.1)**	111.6 (1.7)**	12.3 (0.8)***
60 min after match (T_3)	99.0 (11.5)**	15.6 (0.8)*	12.8 (4)*	385.8 (11.7)**	6.0 (0.2)**	107.5 (1.4)*	1.8 (0.2)*
24 h after match (T_4)	57.2 (7.8)	15.1 (1.0)	5.4 (1.1)	356.1 (16.3)*	6.0 (0.3)*	103.6 (2.4)	1.0 (0.1)
Norm	10–46	6.1–19.3		200–360	3–7.5	50–120	

Data are mean (SEM), n=16. For comparison, reference ranges for adults are listed (Norm).
Significantly different from resting values: *p<0.05; **p<0.01; ***p<0.001.

Key Performance indicator	48kg (n)	52kg (n)	57kg (n)	Average across all three weight groups
Hajime-matte (work)	12.7 ± 7.5	10.3 ± 6.3	10.1 ± 7.4	11.0 ± 7.2
Matte-hajime (rest)	11.5±7.5	9.3 ± 6.4	9.0 ± 7.3	9.9 ± 7.1
kumi kata (gripping)	13.5 ± 8.1	11.7 ± 7.3	12.3 ± 8.7	12.5 ± 8.1
Attack/Defend	11.2 ± 7.0	9.6 ± 6.0	10.2 ± 8.2	10.3 ± 7.1
Transition/Ne Waza	4.0 ± 2.9	3.8 ± 2.8	3.1± 2.8	3.6 ± 2.8

Key Performance indicator	48kg (s)	52kg (s)	57kg (s)	Average time in seconds across all three weight groups
Hajime-matte (work)	21.7 ± 6.8	23.1 ± 6.5	26.4 ± 14.3	23.7 ± 10.0
matte-hajime (rest)	8.1 ± 3.4	8.2 ± 3.3	8.4 ± 3.4	8.2 ± 3.4
kumi kata (gripping)	11.7 ± 4.1	11.4 ± 3.4	11.4 ± 5.4	11.5 ± 4.3
transition/ne waza	14.9 ± 6.6	14.6 ± 9.2	16.8 ± 14.4	15.4 ± 10.6

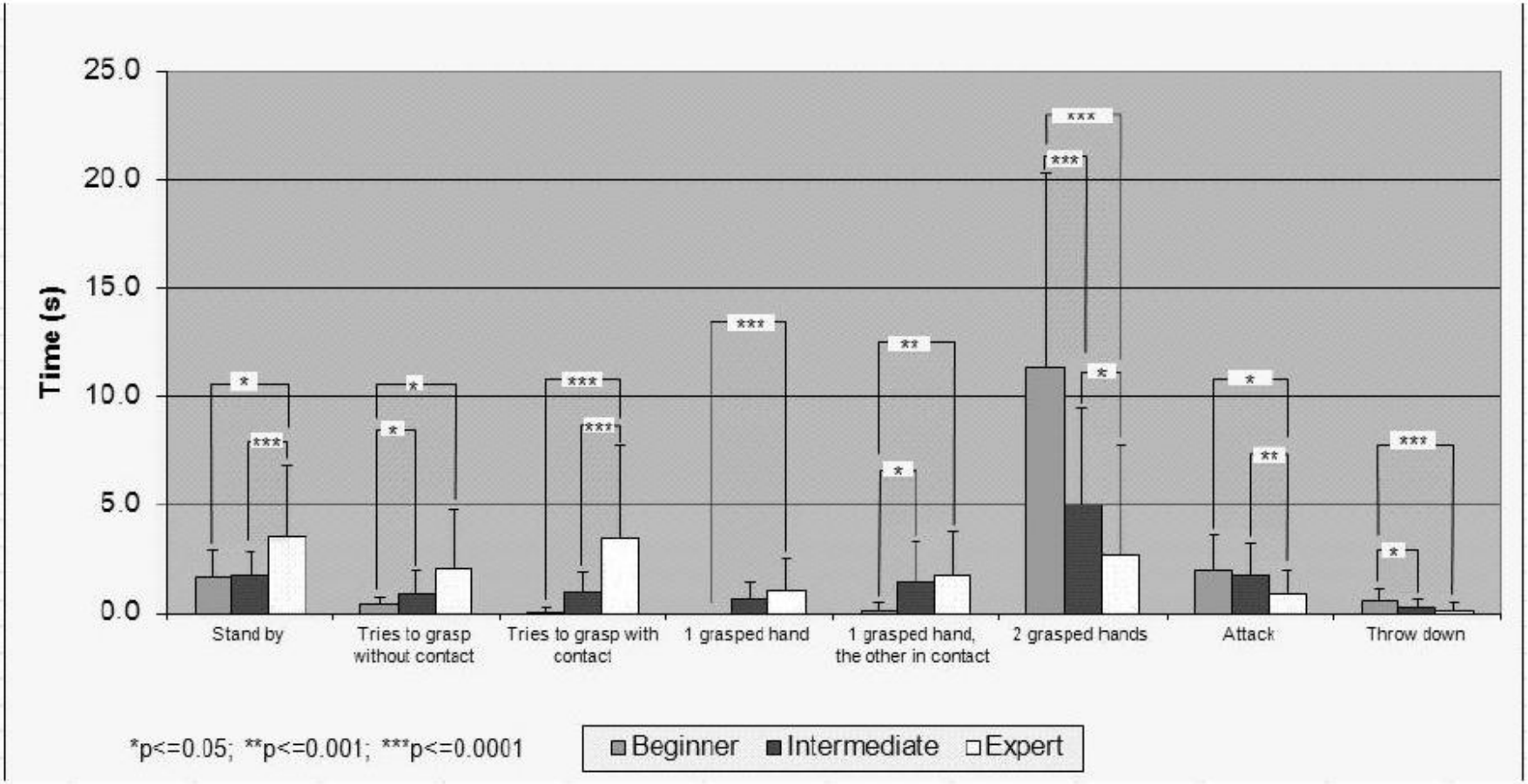

Figure 4: Time (s) spent at different behaviors during a judo match.

Table 1. Anthropometric measures in male half-heavyweight judokas.

	Elite	Subelite	
	Mean (*SEM*)	Mean (*SEM*)	Mean difference (95% CI)
Skinfolds (mm)			
Biceps	4.0 (0.28)	4.2 (0.34)	−0.12 (−1.13 to 0.89)
Triceps	7.4 (1.36)	7.5 (1.14)	−0.12 (−4.22 to 3.98)
Subscapular	12.0 (1.54)	11.4 (0.30)	0.60 (−3.63 to 4.83)
Suprailliac	14.1 (3.18)	14.6 (1.38)	−0.54 (−8.53 to 7.45)
Circumferences (cm)			
Forearm			
Left	33.4 (0.19)	31.5 (0.57)	1.90 (0.34 to 3.46)*
Right	33.6 (0.10)	31.2 (0.62)	2.30 (0.58 to 4.02)*
Upper arm			
Left	40.5 (0.45)	37.5 (0.55)	3.00 (1.37 to 4.63)*
Right	40.4 (0.40)	37.7 (0.54)	2.70 (1.15 to 4.25)*
Thigh			
Left	63.6 (0.68)	61.3 (1.36)	2.30 (−1.20 to 5.80)
Right	63.4 (0.68)	61.2 (1.24)	2.20 (−1.06 to 5.46)
Chest	112.4 (1.28)	110.4 (1.50)	2.00 (−2.57 to 6.57)
Waist	94.5 (1.43)	91.3 (1.36)	3.20 (−1.35 to 7.75)
Total body fat (%)	15.5 (0.78)	15.7 (0.50)	−0.16 (−2.30 to 1.98)

*$p \leq 0.05$.

TABLE 2. Peak torques (Newton-meters) of thigh and shoulder muscles in half-heavyweight judokas.

	Elite	Subelite	
	Mean (*SEM*)	Mean (*SEM*)	Mean difference (95% CI)
Knee extension			
Left	308.06 (16.27)	252.96 (17.09)	55.10 (0.69 to 109.51)*
Right	298.58 (12.81)	256.96 (14.05)	41.62 (−2.21 to 85.45)
Knee flexion			
Left	164.88 (15.62)	146.16 (15.24)	18.72 (−31.60 to 69.04)
Right	170.58 (21.75)	152.12 (14.03)	18.46 (−41.22 to 78.14)
Shoulder external rotation			
Left	80.48 (5.24)	61.50 (1.84)	18.98 (4.69 to 33.27)*
Right	75.48 (2.91)	59.20 (4.09)	16.28 (4.72 to 27.84)*
Shoulder internal rotation			
Left	104.26 (4.65)	98.80 (4.21)	5.46 (−9.01 to 19.94)
Right	105.52 (6.07)	96.92 (8.23)	9.50 (−14.09 to 33.09)

*$p \leq 0.05$.

TABLE 3. Physical fitness tests in male half-heavyweight judokas.

	Elite	Subelite	Mean difference
	Mean (*SEM*)	Mean (*SEM*)	(95% CI)
Handgrip			
Left (kg)	64.3 (1.96)	58.2 (1.99)	6.02 (−0.44 to 12.48)
Right (kg)	69.0 (3.74)	62.6 (2.87)	6.38 (−4.48 to 17.24)
Bench press			
1RM (kg)	164.0 (4.85)	145.0 (5.24)	19.00 (2.53 to 35.47)*
Frequency with BW	23.2 (1.07)	17.2 (1.53)	6.00 (1.70 to 10.30)*
Deep squat			
1RM (kg)	179.0 (5.57)	170.0 (4.74)	9.00 (−7.87 to 25.87)
Frequency with BW	29.0 (0.71)	20.0 (1.22)	9.00 (5.73 to 12.26)*
Deadlift (kg)	238.0 (7.52)	202.0 (4.36)	36.00 (15.96 to 56.04)*
Pull-ups (frequency)	34.0 (3.61)	23.0 (2.57)	11.00 (0.79 to 21.21)*
5-kg ball throw (m)	7.02 (0.53)	5.97 (0.15)	1.05 (−0.21 to 2.31)
Single jump			
High (m)	3.17 (0.08)	3.06 (0.04)	0.11 (−0.11 to 0.33)
Long (m)	2.87 (0.12)	2.60 (0.52)	0.27 (−0.03 to 0.57)
$\dot{V}O_2$max/BW ($ml \cdot kg^{-1} \cdot min^{-1}$)	55.99 (2.24)	48.72 (1.72)	7.27 (0.76 to 13.79)*
$\dot{V}O_2$ max (L)	5.55 (0.29)	4.68 (0.20)	0.87 (0.05 to 1.68)*
Max power test (W)	652.4 (21.20)	536.0 (24.22)	116.40 (42.16 to 190.63)*
30-second Tokui Waza (throws)	15.8 (0.37)	14.0 (0.32)	1.80 (0.67 to 2.93)*

*$p \leq 0.05$.

Table 2: Temporal structure of judo combat

Variable	**Judokas** **Seconds ± SD**
Total work time (TT)	375.06 ± 30.39
Total standing work time (TST)	253.47 ± 21.73
Total ground work time (TGT)	36.78 ± 22.20
Total rest time (TRT)	67.25 ± 21.70
Time per work sequence (TWS)	24.06 ± 7.07
Time per rest period (TRP)	5.73 ± 1.21
Time per ground sequence (TGS)	9.81 ± 3.70
Number of work sequences (NWS)	12.81 ± 2.90
Number of rest periods (NRP)	11.81 ± 2.90
Number of ground sequences (NGS)	3.56 ± 2.16

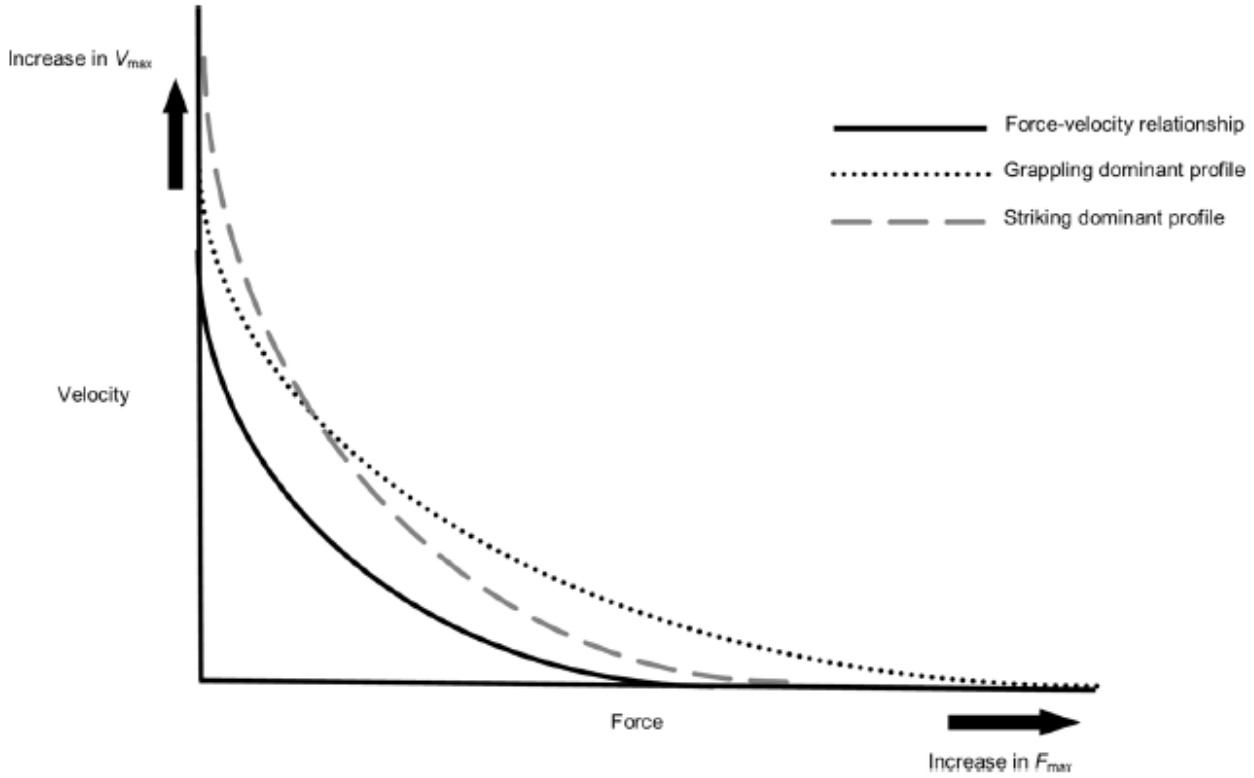

Fig. 3 Proposed lower body power profile of a mixed martial artist based upon combat sport history and dominant strategy. Increased power production occurs at differing magnitudes throughout the spectrum dependent upon profile type (adapted from Haff and Nimphius [158], with permission). V_{max} maximal velocity, F_{max} maximal force

Table 7 Proposed physiological profiles of higher-level mixed martial artists

Physiological quality	Profile type	
	Grappling dominant	Striking dominant
Neuromuscular power	Force emphasis underpinning a shift through to unloaded conditions	Velocity emphasis, with lesser increases under higher force conditions
Maximal force	Both isometric and dynamic strength attributes, with greater overall force capabilities than a striking profile	Greater dynamic than isometric strength capabilities
Anaerobic capabilities	Longer-term anaerobic performance (~30 s). Superior strength endurance	Short-term anaerobic performance (~10 s)
Intermittent anaerobic capabilities	1:2 work-to-rest ratio	1:4 work-to-rest ratio

Table 1: Analysis of sequence (time between *Hajime* and *Matte*) and *break* time regarding the main occurrences in judo matches (measured in seconds)

	Match 1 (s)	Match 2 (s)	Match 3 (s)
Preparation	4 ± 1	4 ± 2	4 ± 1
Grip	16 ± 5	18 ± 3	17 ± 3
Technique	1.4 ± 0.3	1 ± 0.4	1.7 ± 0.5
Groundwork*	17 ± 12 (6 ± 4)	9 ± (4 ± 2)	13 ± 6 (5 ± 2)
Break	7 ± 1	6 ± 2	7 ± 1

* Values represent mean time and standard deviation for action on the ground, considering that not all match sequences have ground action. Values between parentheses are mean and standard deviation values in approximately 11 sequences, four of which are on the ground.

Table 2: Analysis of the percentage of each match sequence and *break* time of main occurrences in judo matches

	Match 1 (%)	Match 2 (%)	Match 3 (%)
Preparation	12 ± 4	13 ± 7	13 ± 3
Grip	49 ± 15	56 ± 9	49 ± 10
Technique	4 ± 1	3 ± 1	5 ± 2
Groundwork*	18 ± 13 (7 ± 5)	11 ± 5 (4 ± 2)	14 ± 7 (5 ± 1)
Break	19 ± 3	16 ± 6	19 ± 3

* Values represent mean time and standard deviation for action on the ground, considering that not all match sequences have ground action. Values between parentheses are mean and standard deviation values in approximately 11 sequences, four of which are on the ground.

Table 1. Basic data of the collected research material - judo fights with: the attack backwards, the attack forwards and the situational attack during the Olympic Games in 2012 in London.*

	Total number of fights	The number of fights with attack forwards	The number of fights with attack backwards	The number of fights with situational attack forwards	Number of fights finished before the time	Number of fights finished before the time of the attack backwards	Number of fights finished before the time of the attack forwards	Number of fights finished before the time of the situational attack
n	34	31	33	27	13	6	7	0
%	100	91.2	97.1	79.4	38.2	17.6	20.6	0
number of points	260	112	138	10	-	60	70	0

* There were observed five double-sided passive penalties for the fight which had no effect on the points scored in the fight - they are not included in Table 1.

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Table 4. The distribution of all carried out attacks in the heavyweight (+100kg) in minutes during the Olympic Games in London 2012.

direction of attack	Min 1.	Min 2.	Min 3.	Min 4.	Min 5.	Play-off 5+
Attack forwards (number)	29	37	32	47	46	37
Attacks backwards (number)	86	64	50	60	52	32
Situational attacks (number)	18	31	17	12	12	7
Total number of attacks	133	132	99	118	110	76

Table 5. The distribution of the Efficiency indicator (Ea) in the heavyweight (+100kg.) in minutes during the Olympic Games in London 2012.

	Min 1.	Min 2.	Min 3.	Min 4.	Min 5.	Play-off 5+
E_a	2.26	4.55	8.08	8.47	5.45	5.26

Table 3. The distribution of the total points number in heavy weight (+100kg) in minutes during the Olympic Games in London 2012.

	Min 1.	Min 2.	Min 3.	Min 4.	Min 5.	play-off 5+
Number of points	25	50	55	61	44	25
The number of attacks awarding points	3	6	8	8	6	4

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Table 1. Phase/subphase criterion.

Phase/subphase	Criteria of analysis
Combat	Period between initiation of the match by the referee (*"hajime"*) and commands to stop the action (*"matte"*) or completion of the match (*"sore-made"*) (5).
Approach	Period between the initiation of the combat phase ("*hajime*") and the execution of the *gripping* (23).
Gripping	Moment of physical contact between the competitors, which continued until the grip initial grip was released or an attack or defensive action was initiated (4).
Attack	Period between the initiation of a throwing technique, as indicated by a reduction in distance/space between athletes ("tsukuri"), until completion of the technique or cessation of the throwing attempt (10,31).
Defense	Moment of an altered body position in specific response to an attack ("*tae-sabaki*") or a counterattack, which was evaluated in manner similar to the *attack* subphase (2).
Groundwork	Any period of time during which an athlete ceased to be in an upright standing position and was executing groundwork techniques (5).
Pause	Period between a referee-designated stop in the action (*"matte"*) and the command to resume action (also *"hajime"*) (5).

Table 3. Accumulated duration of combat, pause, and combat subphases for male and female elite judo athletes from different weight categories.*

	Extra lightweight		Lightweight		Middleweight
Phase	F1	M1	F2	M2	F3
Combat	233.1 (174.5)	227.0 (213.8)	249.7 (204.3)	288.6 (205.7)	228.6 (192.6)
Approach	98.7 (96.5)	110.4 (118.0)	106.6‡ (112.0)	131.0 (121.2)	81.8§ (94.7)
Gripping	51.6 (50.3)	54.9‡§ (49.9)	61.3 (60.7)	75.9‡‖ (60.0)	63.3 (55.8)
Attack	7.8‡ (11.4) †	19.4 (22.9)	11.7 (19.4) †	19.7 (24.4)	13.9‖ (27.1)
Defense	4.3‡§ (7.1) †	18.8 (25.2)	6.8‖ (14.1) †	15.8¶ (24.9)	7.5‖ (18.5)
Groundwork	39.6‡§ (59.3) †	13.2¶ (19.4)	15.1‖ (36.3)	13.8‡¶ (19.0)	11.8‖ (31.1)
Pause	56.8 (78.8)	51.8¶ (55.1)	66.7 (88.2)	56.3¶ (52.8)	49.6 (70.6)

	Middleweight	Heavyweight		
Phase	M3	F4	M4	Statistics
Combat	† 327.3 (178.5)	213.0 (160.1)	219.6 (234.3)	$H = 41.428$; $p < 0.001$; $\eta^2 = 0.03$
Approach	† 128.7 (119.2)	85.1 (90.3)	96.0 (106.8)	$H = 50.690$; $p < 0.001$; $\eta^2 = 0.04$
Gripping	† 98.6§‖ (66.5)	62.7 (45.4)	72.8 (72.0)	$H = 75.426$; $p < 0.001$; $\eta^2 = 0.05$
Attack	21.5 (26.1)	15.6 (23.8)	20.9 (36.7)	$H = 56.705$ $p < 0.001$; $\eta^2 = 0.04$
Defense	† 22.0¶ (31.9)	8.7 (15.7)	8.9‡§ (21.7)	$H = 124.300$; $p < 0.001$; $\eta^2 = 0.09$
Groundwork	9.5§ (14.8)	17.3 (29.4) †	4.6§‖ (10.5)	$H = 115.650$; $p < 0.001$; $\eta^2 = 0.08$
Pause	45.1¶ (41.5)	69.9 (86.5) †	29.4‡§‖ (40.9)	$H = 84.265$; $p < 0.001$; $\eta^2 = 0.06$

*Data are presented as median (interquartile range), seconds.
†Significant difference between men and women in the same weight category.
‡Significant difference compared with the middleweight category of the same sex.
§Significant difference compared with the lightweight category of the same sex.
‖Significant difference compared with the extra lightweight category of the same sex.
¶Significant difference compared with the heavyweight category of the same sex.

Table 4. Duration of combat, pause, and combat subphases in an individual combat/pause sequence for men and women elite judo athletes from different weight categories.*

	Extra lightweight		Lightweight		Middleweight
Phase	F1	M1	F2	M2	F3
Combat	26.7 (15.4)	22.9† (10.0)	24.6 (11.9)	24.8† (8.7)	25.7 (12.6)
Approach	5.0 (2.85) ‖	6.1 (2.38)	5.3 (2.5) ‖	6.1 (2.7)	5.2 (3.1)
Gripping	3.3† (1.4) ‖	3.8 (2.2)	3.4† (1.7) ‖	4.2 (2.4)	3.6 (1.9)
Attack	0.6 (0.6) ‖	1.4 (1.8)	0.8 (1.0) ‖	1.9 (2.0)	0.8 (1.4)
Defense	0.9†§¶ (1.0) ‖	3.2 (3.1)	1.5‡ (2.5) ‖	3.7 (3.0)	2.1‡ (2.8)
Groundwork	5.6§ (6.8) ‖	1.8 (1.4)	2.4‡ (4.7) ‖	2.0 (1.3)	3.2 (6.6)
Pause	7.3 (4.0) ‖	5.4 (3.2)	6.6 (5.9) ‖	4.9† (2.9)	6.8 (5.8)

	Middleweight	Heavyweight		
Phase	M3	F4	M4	Statistics
Combat	23.9 (12.6)	25.3 (7.1)	28.5‡§ (14.8)	$H = 17.356$; $p = 0.015$; $\eta^2 = 0.01$
Approach ‖	6.5 (2.0)	5.7 (3.9)	6.6 (3.0)	$H = 78.913$; $p < 0.001$; $\eta^2 = 0.06$
Gripping ‖	4.3 (1.8)	4.5‡§ (2.4)	4.3 (2.1)	$H = 102.800$; $p < 0.001$; $\eta^2 = 0.07$
Attack ‖	1.9 (2.0)	0.9 (2.0) ‖	2.5 (2.9)	$H = 210.100$; $p < 0.001$; $\eta^2 = 0.15$
Defense ‖	4.0 (3.4)	2.6‡ (3.8)	3.9 (4.3)	$H = 206.540$; $p < 0.001$; $\eta^2 = 0.15$
Groundwork ‖	1.8 (1.3)	3.8 (7.0) ‖	1.9 (1.9)	$H = 99.722$; $p < 0.001$; $\eta^2 = 0.07$
Pause ‖	4.4 (2.8)	8.8 (6.2) ‖	4.0§ (2.9)	$H = 111.610$; $p < 0.001$; $\eta^2 = 0.08$

*Data are presented as median (interquartile range), seconds.
†Significant difference compared with the heavyweight category of the same sex.
‡Significant difference compared with the extra lightweight category of the same sex.
§Significant difference compared with the lightweight category of the same sex.
‖Significant difference between men and women in the same weight category.
¶Significant difference compared with the middleweight category of the same sex.

Table 1. Frequency of throw techniques used during Judo Olympic Tournaments (2012) by males and females from different weight categories.

Technique of throws codes	Total	Males	Females	Male groups/weight categories				Female groups/weight categories			
CODE				Group 1	Group2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
PLmaxA	90	49	41	9	24	14	2#	8	14	12	7
PLvA	81	55	26*	17	23**	14**	1**	2	13	8	3
CAL	77	40	37	9	17	11	3	6	15	15##	1#
CTL	55	27	28	2	12	8	5*	1	12	12	3
PLminA	35	20	15	2	7	8	3	1	7	3	4
PLmidA	11	3	8	0	1	1	1	0	4	2	2
CA	10	9	1	0	6	2	1	0	0	0	1
Total	359	203	156	39	90	58	16	18	65	52	21

*PLmaxA – Physical lever applied with max arm; PLvA – Physical lever applied with variable arm; CAL – Couple of forces applied by arm or arms and leg; CTL – Couple of forces applied by trunk and legs; PLminA – Physical lever applied with min arm; PLmidA – Physical lever applied with middle arm ; CA – Couple of forces applied by arms. * Significant difference between males and females; # significant difference between group 1 and group 4; ** significant difference between group 1 and 2, 3, 4 groups, ## significant difference between groups 2nd and 3rd*

Table 2. Frequency of grappling techniques used during Judo Olympic Tournaments (2012) by males and females from different weight categories.

Grappling actions codes		Total	Males	Females	Male groups/weight categories				Female groups/ categories weight			
CODE					Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
KGARAMI	1	0	1	0	0	0	0	0	0	0	1	
KHISHIGI	19	9	10	5	3	1	0	0	6	3	1	
OKESA	11	7	4	2	2	1	2	0	3	1	0	
OSHIHO	30	19	11	2	9	6#	2	1	2	5	3	
SRESP	12	8	4	2	4	0	2	1	3	0	0	
SVASC	4	0	4*	0	0	0	0	2	2	0	0	
Total	77	43	34	11	18	8	6	4	16	9	5	

KGARAMI – joint techniques of the entangled joint lock type; KHISHIGI – joint techniques of the bending and pressing against elbow joint type; OKESA- pinning techniques of the scarf type; OSHIHO – pinning techniques of the four corner hold; SRESP – respiratory chocking; SVASC – vascular chocking. * Significant difference between males and females, # significant difference between group 1st and group 3rd.

Table 3. Number of penalties imposed during fights of men and women according to weight categories.

Instances of penalties and codes	Total	Males	Females	Male groups/weight categories				Female groups/weight categories			
CODE				Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
P29 Non-combativity	364	238	126*	21	95	70 #, ##	52 **	20	59	31	16
Other penalties	227	126	101	16	68	32	10	15	55	17	14
Total	591	364	227	37	163	102	62	35	114	48	30

* Significant difference males from females, # Significant difference between group 1st and group 4th, ** significant difference between group 2nd and group 4th, ## significant difference between group 3rd and group 4th.