Heart Rate Intensity Monitoring in Wushu Athletes: Evaluating Training Vs. Match Load And Recovery

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ABSTRACT

In combat sports like Wushu, due to weight divisions, body composition and for the execution of technical-tactical movements, cardiovascular and muscular endurance are a concern. Specific training methods and fitness tests are necessary to assess the physical readiness of Wushu players, as well as the monitoring of heart rate for training load quantification and heart rate recovery to measure endurance and aerobic preparedness. A total of 16 (10 Male & 6 Female) Indian National medallist Wushu players attending National training camp were monitored during their specific preparatory training period. The variables like body composition estimation, heart rate intensity during punching-kicking on bags, heart rate recovery at 1min, 2min. after punching-kicking on bags, heart rate intensity during match bouts and heart rate recovery in first two minutes after match bouts were measured to determine the respective training load differences. To look after the difference & relationship between Wushu bout and Wushu specific training on punching bag for above mentioned variables Mann Whitney U Test & Pearson's Coefficient Correlation was applied. The results of heart rate intensity, heart rate recovery at 1min, 2min. and Skeletal muscle mass % had shown positive relationship in punching & kicking on bag as well as in Wushu bout. Heart rate after training (172.12 ±6.15 in bpm) was significantly lower than HR after 3rd i.e. the last bout of fight (182.94 ± 4.51). Percentage heart Rate maximum after training and fight (88.13 ± 2.96 and 93.67 ± 2.12) have shown positive correlation. This study implies that these training load and intensity is lesser than the combatants' match load and intensity and can be applied for physical preparedness of the athletes. Further regression analysis for bag fight-based match specific endurance and aerobic preparedness prediction is recommended for a better practical applicability.

Keywords: Combat Sports, Aerobic Conditioning, Heart Rate Recovery, Wushu Sanshou, Heart rate Intensity.

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INTRODUCTION

Combat sports such as Wushu demand a distinctive blend of technical skill, tactical precision, and physical conditioning, shaped by the sport's intense competitive nature and strict weight categories. Athletes are required to maintain optimal body composition through nutritional control while developing strength, speed, flexibility, and especially cardiovascular and muscular endurance to sustain high performance. The sport's explosive yet repetitive movements require not only power but also technical accuracy and control over extended durations. Cardiovascular endurance ensures athletes can perform continuously without early fatigue, while muscular endurance supports repeated, high-intensity actions that are crucial for competitive success (Huang et al., 2018; Li et al., 2022; Ramos-Campo et al., 2018).

Heart rate (HR) has been observed to increase significantly across rounds in male taekwondo, boxing, and kickboxing matches. Similarly, both HR and maximal heart rate (HRmax) show a significant rise during successive karate and judo matches in young men and boy athletes. (Slimani et al., 2018). Study assessed cardiovascular responses to different technical and tactical situations in kick-boxing, aiming to help coaches evaluate competitor preparedness. Nine highly trained kickboxers (average age 19.9 years) participated. The study found significant heart rate (HR) decreases between rounds: 1st to 2nd ($F = 4.99$, $p = 0.015$) and 2nd to 3rd ($F = 5.01$, $p = 0.015$). Peak heart rates were higher in matches (190.11 bpm) compared to bag work (185.56 bpm) and sparring (185.78 bpm). The HR decrease was 23% for bag work, 18% for sparring, and 14% for matches. These results indicate that matches are more demanding than training, underscoring the need for match-like training scenarios. (Gavrilovic et al., 2016). The study of HR kinetics in trained wrestlers revealed significant differences in heart rate recovery (HRR) 60s and non-linear analysis of heart rate variability (HRV) between highly trained (HT) and moderately trained (MT) individuals. Specifically, differences were observed in SD1 30-45s and SD1 45-60s, indicating that heart rate dynamics during the first minute post-exercise are associated with training level and can be utilized as an indicator for autonomic cardiovascular control in Brazilian jiu-jitsu wrestlers (Henríquez Olguín et al., 2013).

Assessing the physical readiness of Wushu athletes is crucial, with heart rate monitoring serving as a key indicator of training load and recovery. It provides a quantifiable measure of exertion, helping coaches ensure athletes train within optimal intensity ranges to enhance endurance while avoiding overtraining (Gabbett, 2016). Monitoring during sport-specific sessions (e.g., punching and kicking drills) and tracking heart rate recovery offers insights into cardiovascular fitness and endurance. Training methods such as high-intensity interval training (HIIT) and sport-specific drills replicate competition demands, while recovery techniques sustain peak performance. Readiness is further assessed through field tests simulating competition and laboratory measures of physiological parameters (Buchheit & Laursen, 2014;

Gordon & O'Neill, 2017). By combining these approaches with heart rate monitoring, this study delivers a comprehensive evaluation of Wushu athletes' preparedness for high-level performance.

MATERIAL AND METHODS

A total of 16 Indian National-level Wushu athletes (10 male and 6 female) participating in the National Training Camp were evaluated during their specific preparatory phase. The study assessed multiple physiological parameters, including body composition, heart rate (HR) intensity, and HR recovery under both training and competition (bout) conditions.

Body composition was measured using a Tanita Body Composition Analyser, following standard operating procedures. Measurements were taken in the morning session, before training, and in a fasted state.

Heart rate intensity was continuously monitored using a Polar Heart Rate Monitor during punching–kicking drills on the bag (training load), official Wushu bouts (competitive load), and recovery phases at 1-minute and 2-minute intervals post-exercise. These measures were used to evaluate aerobic fitness differences between training and match conditions.

Heart rate (HR) response was examined for mean and peak HR during training and competitive bouts to quantify relative cardiovascular load and intensity zones. Body composition measures, including fat percentage, muscle mass, and BMI, were analysed to assess how physiological profiles influenced aerobic and recovery responses. The Wushu game assessment compared HR trends and recovery kinetics between training drills and match play, highlighting load specificity and recovery efficiency under real-competition stress.

To analyse the data, the Mann–Whitney U test was employed to determine differences between training and bout HR parameters. The Pearson's Product–Moment Correlation Coefficient (r) was applied to examine relationships between HR variables, including training and bout intensity, recovery indices, and body composition metrics.

RESULTS AND DISCUSSION:

The study on Wushu athletes revealed several significant findings. There was a positive relationship among

Table 1: Anthropometry and heart rate maximum of wushu athletes.

Participants	Age (years)	Height (cm)	Weight (kg)	Body Fat%	SMM%	HRmax (bpm)
Women (n = 06)	26 ± 3.85	168.17 ± 5.98	70 ± 7.45	28.68 ± 3.72	39.47 ± 3.00	194.33 ± 4.23
Men (n = 10)	24.4 ± 2.41	176.1 ± 4.18	69.64 ± 9.15	11.39 ± 3.3	50.02 ± 1.9	93.32 ± 2.48
Total (n = 16)	24.69 ± 3.22	173.12 ± 6.17	69.78 ± 8.29	17.86 ± 9.27	46.06 ± 5.74	195.31 ± 3.22

Values are expressed as mean±SD, SMM= skeletal muscle mass, HRmax= heart rate maximum.

Table 2: Heart rate monitored of all the elite men and women Wushu Sanshou players (n = 16) during training and matches.

HR during training in bpm and % (n = 16), Combined					
HR (PT)	172.12 ± 6.15	HR before Fight (bpm)		124.06 ± 5.13	
% HRmax (PT)	88.13 ± 2.96				
HRrec (30 sec)	162.37 ± 9.33				
HRrec (1 min)	149.56 ± 8.8	HR after B1	175 ± 10.98	% HRmax (B1)	88.79 ± 4.05
HRrec (90 sec)	138.62 ± 9.47	HR after B2	172.5 ± 11.62	% HRmax (B2)	87.22 ± 4.45
HRrec (2 min)	129.44 ± 9.32	HR after B3	182.8 ± 4.87	% HRmax (B3)	93.67 ± 2.12
HRrec (in 1 min)	22.56 ± 6.28	HRrec (in 1 min)	24.2 ± 6.7	HRrec (1min)	161.12 ± 7.47
HRrec (in 2 min)	42.69 ± 8.85	HRrec (in 2 min)	43.5 ± 9.49	HRrec (2 min)	144.06 ± 8.54

Values are expressed as mean±SD, HR= heart rate, HRrec= heart rate recovery, % HRmax (PT)= heart rate maximum percentage (post-training), B1= 1st bout, B2= 2nd bout, B3= 3rd bout.

Table 3: Heart rate monitored of all the elite men wushu sanshou players (n = 10) during training and matches.

HR response during training in bpm and % (n = 10), men players					
HR (PT)	170.4 ± 6.29	HR before Fight		123.3 ± 3.13	
% HRmax (PT)	86.44 ± 3.11				
HRrec (30 sec)	159.2 ± 9.3				
HRrec (1 min)	145.9 ± 6.87	HR after B1	175 ± 10.98	% HRmax (B1)	89.3 ± 5
HRrec (90 sec)	133.1 ± 4.91	HR after B2	172.5 ± 11.62	% HRmax (B2)	88.03 ± 5.36
HRrec (2 min)	123.3 ± 4.4	HR after B3	182.8 ± 4.87	% HRmax (B3)	93.32 ± 2.48
HRrec (in 1 min)	24.5 ± 6.84	HRrec (in 1 min)	24.2 ± 6.7	HRrec (1min)	158.6 ± 6.15
HRrec (in 2 min)	47.1 ± 8.44	HRrec (in 2 min)	43.5 ± 9.49	HRrec (2 min)	139.3 ±6.72

Values are expressed as mean±SD, HR= heart rate, HRrec= heart rate recovery, B1= 1st bout, B2= 2nd bout, B3= 3rd bout.

Table 4: Heart rate monitored of all the women wushu sanshou players (n = 06) during training and matches.

HR during training in bpm and % (n = 06), women players					
HR (PT)	175 ± 5.14	HR before Fight		125.33 ± 7.63	
% HRmax (PT)	90.05 ± 1.34				
HRrec (30 sec)	167.67 ± 7.2				
HRrec (1 min)	155.67 ± 8.71	HR after B1	170.83 ± 2.32	% HRmax (B1)	87.93 ± 1.68
HRrec (90 sec)	147.83 ± 7.94	HR after B2	166.83 ± 1.72	% HRmax (B2)	85.88 ± 2.09
HRrec (2 min)	139.67 ± 4.97	HR after B3	183.17 ± 4.26	% HRmax (B3)	94.26 ± 1.32
HRrec (in 1 min)	19.33 ± 3.78	HRrec (in 1 min)	17.83 ± 4.49	HRrec (1min)	165.33 ± 8.09
HRrec (in 2 min)	35.33 ± 1.75	HRrec (in 2 min)	31.17 ± 2.48	HRrec (2 min)	152 ± 4.05

Values are expressed as mean±SD, HR= heart rate, HRrec= heart rate recovery, B1= 1st bout, B2= 2nd bout, B3= 3rd bout.

heart rate intensity, heart rate recovery, and skeletal muscle mass percentage during both bag training and Wushu bouts. Specifically, the heart rate after training sessions (172.12 ± 6.15 bpm) was significantly lower than the heart rate after the final bout of a fight (182.94 ± 4.51 bpm). Additionally, the percentage of maximum heart rate after training (88.13 ± 2.96) and after fights (93.67 ± 2.12) also showed a positive correlation.

The graphical representation of Figure 2 compares heart rate (HR) recovery during training and matches for Wushu athletes, showing that Pre-HR is slightly higher before matches compared to training. Post-HR is significantly higher after matches than training. HR 1-minute recovery is also higher after matches compared to training, and HR 2-minute recovery follows the same pattern, with higher values after matches than training. These findings indicate that matches impose a greater cardiovascular demand and result in slower HR recovery, suggesting the need for high-intensity, match-like scenarios in training to better prepare athletes for competition.

The results indicate that athletes who demonstrate better cardiovascular and muscular endurance in training tend to perform well in actual matches. The significant increase in heart rate during matches compared to training sessions suggests that real competition imposes a higher cardiovascular demand. Despite this higher demand, the similar trend in heart rate response between training and matches implies that current training regimens are effectively preparing

Table 5: Correlation between training and match-based heart rate for men and women elite Indian wushu sanshou players (n = 16)

Correlations, N =16		HRpt	30sHRpt	1minHRpt	90sHRpt	2minHRpt	1minRecHRpt	2minRecHRpt	Age (in years)	AHRmax	%AHRmaxpt	HRbf	HRpb1	HRpb2	HRpb3	1minHRpb	1minRecHRpb	2minHRpb	2minRecHRpb	%HRmax1b	%HRmax2b	%HRmax3b	BM	BFP	SMMP
HRpt	R	1																							
	P																								
30sHRpt	R	.751**	1																						
	P	0.001																							
1minHRpt	R	.708**	.838**	1																					
	P	0.003	0																						
90sHRpt	R	.568*	.694**	.805**	1																				
	P	0.022	0.003	0																					
2minHRpt	R	0.404	.603*	.690*	.924**	1																			
	P	0.121	0.047	0.014	0																				
1minRecHRpt	R	-0.002	-0.439	-.715**	-.558*	-0.445	1																		
	P	0.994	0.089	0.002	0.025	0.084																			
2minRecHRpt	R	0.27	-0.008	-0.145	-.578*	-.772**	0.407	1																	
	P	0.312	0.976	0.593	0.019	0	0.068																		
Age (in years)	R	-0.345	-0.07	-0.462	-0.151	0.014	0.309	-0.254	1																
	P	0.191	0.348	0.072	0.578	0.96	0.244	0.343																	
AHRmax	R	0.345	0.307	0.462	0.151	-0.014	-0.309	0.254	-1.000**	1															
	P	0.191	0.248	0.072	0.578	0.96	0.244	0.343	0																
%HRmaxpt	R	.686**	.641**	.512*	.526*	0.433	0.151	0.16	0.131	-0.131	1														
	P	0	0.007	0.043	0.037	0.094	0.578	0.555	0.629	0.629															
HRbf	R	0.064	-0.198	-0.017	0.024	0.08	0.106	-0.026	0.138	-0.138	0.157	1													
	P	0.757	0.462	0.95	0.93	0.769	0.695	0.924	0.609	0.609	0.561														
HRpb1	R	0.21	0.244	0.296	-0.232	-0.442	-0.208	.611*	-0.467	0.467	-0.006	0.035	1												
	P	0.434	0.363	0.266	0.385	0.085	0.439	0.012	0.068	0.068	0.983	0.897													
HRpb2	R	0.093	0.367	0.292	-0.264	-0.418	-0.318	-.504*	-0.425	0.425	-0.11	-0.205	-.726**	1											
	P	0.732	0.163	0.273	0.323	0.107	0.23	0.047	0.104	0.104	0.685	0.447	0.001												
HRpb3	R	.617**	.555*	.596*	0.271	0.083	-0.034	0.401	-0.447	0.447	-.641**	-0.112	0.264	.597*	1										
	P	0	0.026	0.015	0.31	0.759	0.901	0.06	0.083	0.083	0.007	0.679	0.325	0.268											
1minHRpb	R	0.424	.616*	.674**	.680**	.561*	.808**	-0.206	-0.456	0.456	0.222	-0.176	0.133	0.271	0.481	1									
	P	0.101	0.011	0	0.004	0.024	0	0.395	0.076	0.076	0.408	0.515	0.625	0.31	0.059									
1minRecHRpb	R	0.078	-0.317	-.581*	-.583*	-.577*	.690**	.661**	0.21	-0.21	0.186	0.125	0.03	-0.104	0.138	-.802**	1								
	P	0.775	0.231	0.018	0.018	0.019	0	0.005	0.435	0.435	0.491	0.645	0.913	0.702	0.61	0									
2minHRpb	R	0.136	0.243	0.43	.765**	.907**	-0.469	-.569**	0.066	-0.066	0.175	0.018	-.612*	-0.447	-0.012	.578*	-.691**	1							
	P	0.616	0.364	0.097	0.001	0	0.067	0	0.807	0.807	0.516	0.947	0.012	0.083	0.965	0.019	0.005								
2minRecHRpb	R	0.261	0.044	-0.101	-.548*	-.709**	0.397	.980**	-0.266	0.266	0.144	0.068	.661**	.511*	0.475	-0.285	.686**	-.885**	1						
	P	0.33	0.871	0.709	0.028	0.001	0.128	0	0.319	0.319	0.595	0.802	0.005	0.034	0.063	0.285	0.003	0							
%HRmax1b	R	0.114	0.165	0.167	-0.008	-0.482	-0.123	-.587*	-0.163	0.163	0.443	0.064	-.940**	-.658**	0.135	-0.012	0.105	-.654**	.638**	1					
	P	0.676	0.542	0.535	0.245	0.058	0.649	0.017	0.547	0.547	0.85	0.758	0	0.006	0.619	0.966	0.699	0.006	0.008						
%HRmax2b	R	-0.089	0.09	0.176	-0.328	-0.442	-0.255	0.459	-0.14	0.14	-0.078	-0.152	.659**	.957**	0.18	0.157	-0.055	-0.456	0.465	.666**	1				
	P	0.975	0.345	0.515	0.215	0.087	0.341	0.074	0.606	0.606	0.775	0.573	0.008	0	0.505	0.562	0.84	0.076	0.057	0.005					
%HRmax3b	R	.631**	0.374	0.306	0.181	0.098	0.189	0.335	0.349	-0.349	.788**	-0.053	-0.055	0.013	.735**	0.187	0.304	0.035	0.32	0.027	0.095	1			
	P	0.009	0.154	0.349	0.501	0.717	0.482	0.505	0.352	0.352	0	0.979	0.839	0.963	0.001	0.489	0.253	0.898	0.227	0.92	0.733				
BM	R	-0.465	-0.192	-0.053	-0.161	-0.205	-0.381	-0.107	0.157	-0.157	-0.411	0.1	0.334	0.294	-0.459	-0.119	-0.179	-0.211	-0.027	0.426	0.37	-0.379	1		
	P	0.07	0.477	0.846	0.551	0.446	0.145	0.692	0.562	0.562	0.114	0.712	0.207	0.269	0.074	0.662	0.507	0.432	0.92	0.1	0.159	0.147			
BFP	R	0.111	0.114	0.438	.666**	-.700**	-0.466	-.719**	0.296	-0.296	0.287	0.189	-0.184	-0.22	-0.179	0.319	-.505*	-.677**	-.674**	-0.095	-0.157	0.024	0.337	1	
	P	0.83	0.236	0.089	0.005	0	0.056	0.002	0.266	0.266	0.282	0.485	0.495	0.414	0.508	0.199	0.046	0.004	0.004	0.727	0.612	0.93	0.202		
SMMP	R	-0.138	-0.298	-0.445	-.645**	-.757**	0.489	.701**	-0.254	0.254	-0.274	-0.212	0.167	0.195	0.188	-0.339	.511*	.666**	.668**	0.091	0.135	0.017	-0.353	.972**	1
	P	0.611	0.262	0.084	0.007	0.001	0.055	0.002	0.342	0.342	0.305	0.229	0.536	0.468	0.486	0.199	0.043	0.005	0.005	0.738	0.645	0.951	0.18	0	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Pearson Correlation = R
Sig. (2-tailed) = P

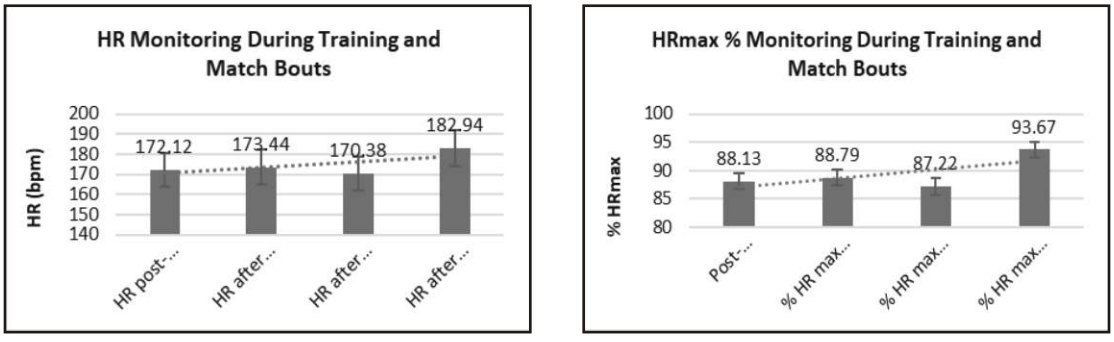

Figure 1: Absolute HRmax (bpm) and percentage (%) of HRmax observed during training and bouts of all combined (men and women) wushu sanshou players.



Figure 2: Absolute HRmax and percentage (%) of HRmax observed during training and bouts of the elite Indian men (n=10) Wushu sanshou players.



Figure 3: Absolute HRmax and percentage (%) of HRmax observed during training and bouts of the elite Indian women (n=6) Wushu sanshou players

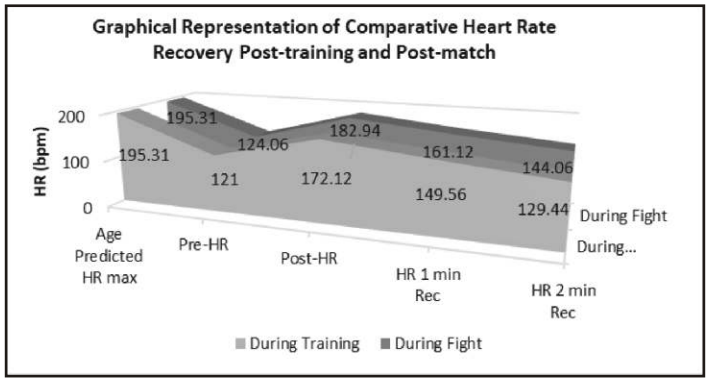

Figure 4: Graphical representation of comparative heart rate recovery of the participants during training and matches.

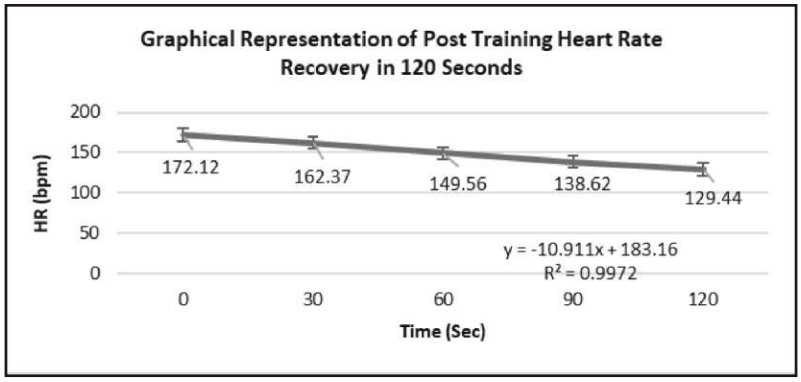

Figure 5: Graphical representation of post-training HR recovery in 120 seconds of all the elite Indian men and women wushu sanshou players (n = 16).

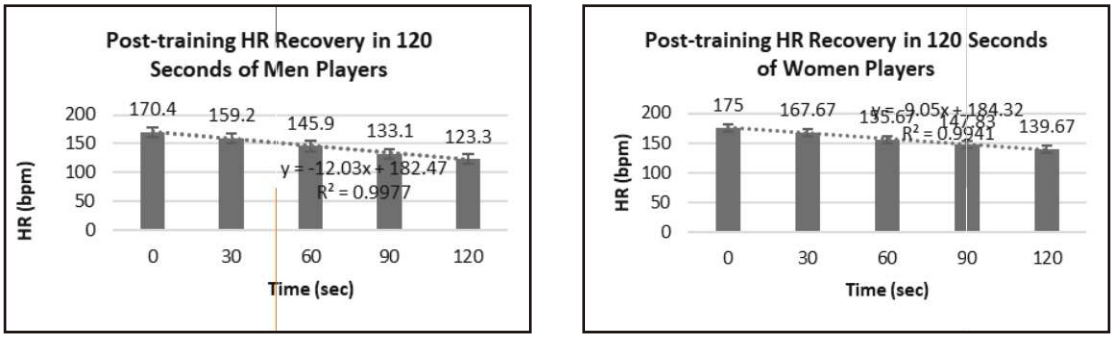

Figure 6: Graphical representation of post-training HR recovery in 120 seconds of all the elite Indian men wushu sanshou players (n = 10) and women wushu sanshou players (n = 06).

athletes for competition. However, the fact that training intensity is slightly lower than match intensity suggests a need for more high-intensity sparring and drills that replicate match conditions to better prepare athletes for the peak demands of competition.

In comparison to other sports, the need for high-intensity training to match competition conditions is also evident. For example, in sports like football and basketball, players often participate in high-intensity drills and scrimmages to simulate game conditions, and endurance sports like running and cycling require training at high intensities to build the necessary resilience for races. This underscores the universal importance of training that closely mimics the intensity of actual competition.

The analysis revealed that Wushu bouts elicited higher cardiovascular demands than training sessions, reflected by elevated relative heart rate values during competition. This suggests that the intensity of match play—driven by maximal technical, tactical, and psychological exertion—surpasses that of regular training (Buchheit & Laursen, 2014; Gabbett, 2016). Consequently, current training loads may not adequately mirror competitive stress, emphasizing the need for integrating more high-intensity, sport-specific drills to better simulate match conditions (Ramos-Campo et al., 2018; Li et al., 2022).

The intensity of combat HR as a percentage of HRmax varies 90% to 94% in judo, 86% to 100% in taekwondo, 83% to 94% in karate, and approximately 95% in Muay-Thai matches. Studies have also indicated that coaches, sports scientists, and athletes can utilize HR to (i) assess the cardiovascular demand on athletes and (ii) monitor exercise intensity during combat sports matches (slimani et al., 2018) Heart rate serves as a valuable indicator of cardiovascular demand and physiological response during Brazilian jiu-jitsu matches, which event is close as a combat event to Wushu Sanda event, reflecting the intensity of effort and providing insights into the athlete's metabolic and cardiovascular adaptations to the combative activity (Andreato, Vidal, et al., 2016).

Heart rate recovery (HRR) analysis showed slower autonomic recovery after bouts than training, indicating greater physiological stress and delayed parasympathetic reactivation (Buchheit & Laursen, 2014). Minor sex-related differences were observed, with men exhibiting higher peak HR and women showing slightly slower recovery, though the small sample limits conclusions (Li et al., 2022). These findings highlight the need for HR-based monitoring in daily training to align intensity with competition demands and emphasize structured recovery protocols to prevent overtraining during dense competitive periods (Gordon & O'Neill, 2017; Huang et al., 2018).

CONCLUSION

The study's findings indicate that current Wushu training practices are on the right track for preparing athletes, as evidenced by the similar trend in heart rate response during training and matches. However, there is a clear need to increase training intensity to better match the cardiovascular demands of actual competition. By doing so, athletes can be

better conditioned to handle the physical demands of Wushu matches, ensuring they are not only fit but also resilient under competitive conditions.

Heart rate monitoring and recovery analysis indicate that Wushu bouts produce greater autonomic stress and slower post-exercise recovery compared to training (Buchheit & Laursen, 2014). These findings underscore the importance of structured recovery interventions and consistent HR-based monitoring to balance adaptation and fatigue. By aligning training intensity with competition-specific demands and systematically tracking HR recovery, coaches can enhance conditioning, minimize overtraining risk, and improve performance readiness.

FUTURE IMPLICATIONS

The study recommends incorporating more high-intensity sparring sessions and training drills that simulate the intensity and pace of actual matches. This can help athletes adapt to the peak demands of competition. Additionally, further regression analysis is suggested to develop predictive models for match-specific endurance and aerobic preparedness. These models can help coaches and trainers fine-tune training regimens to meet the specific demands of competition more effectively. By implementing these strategies, athletes can achieve higher performance levels and maintain a competitive edge in wushu.

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