International Journal of
EXERCISE SCIENCE

Original Research

Heart Rate Variability as a Neuroautonomic Marker to Assess the Impact of Karate Training – An Observational Pediatric Study

PUNEET BHATTACHARYA†[1,2], SRIDIP CHATTERJEE‡[2], SAMIRAN MONDAL‡[1], and DILIP ROY†[2]

[1]Department of Physical Education and Sports Science, Visva-Bharati (Central University), Santi Niketan, Bolpur, West Bengal, INDIA; [2]Department of Physical Education, Jadavpur University, Kolkata, West Bengal, INDIA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 16(2): 342-352, 2023. Habitual physical activity improves heart functions and parasympathetic tone; Karate training is considered as a moderate physical activity with rhythmical breathing patternology. Heart rate variability (HRV) is an electrophysiological tool which measures cardio autonomic homeostasis; is used in the present study as an indirect marker to measure neurocognitive development with karate training. The aim of the present study was to find out the impact of regular karate training on cardiac autonomic responses through Heart Rate Variability (HRV) between karate players and age-sex matched active controls. A total of 30 male school-going children were evaluated; fifteen were experienced male karate practitioners (9.5±1.26 years) and fifteen controls (10.6±1.57 years). The time and frequency domain measures of HRV were taken into account after check for normality distribution, followed by t-test for comparison of Mean±SD. Frequency domain measures; low frequency normalized unit (LF nu) and low frequency is to high frequency ratio (LF/HF ratio) both showed significant reduction in the karate group which quantified sympathetic disposition while High frequency normalized units (HF nu) reflected a significant rise and it predicted increase in parasympathetic tone. Karate practitioners show higher HRV measures and more involvement of the parasympathetic nervous system which help in stress resilience and improved recovery time. This training if performed regularly from an early age can improve cardiac health which is very pertinent in the present times.

KEY WORDS: Cardio autonomic homeostasis, moderate physical activity, parasympathetic tone, stress resilience, cardiac health

INTRODUCTION

Neurobiological mechanisms have been investigated in recent times and prove the interplay between cardiorespiratory fitness and cognitive enhancing benefits of physical exercise. Heart rate variability (HRV) is a reliable non-invasive index which measures the interactions between the autonomic nervous system and the cardiovascular system (1). Identified by a series of time and frequency domains it expresses bio signaling of the heart rhythms with changing environmental situations. It expresses the dominance of the parasympathetic and sympathetic nervous systems of the brain indirectly affecting the heart through the vagal neural pathways (17).

HRV is an independent marker which circuitously reflects cognitive control, thus assesses the cardiac autonomic status of an individual. The dimensions of sustained and selective attention, memory, perception, behavioural inhibition, cognitive flexibility and loading can be viewed through its assessment (11). Hon and Lee in 1965 first recorded the significance of HRV clinically, which is the result of temporal oscillations between heart beats. In this study HRV has been measured through short term recordings of two areas; the time domain and frequency domain analysis, the complete detail of which are given in Table 1 below (13).

There is multiple evidence that psychophysiological stress negatively impacts the autonomic equilibrium and it results in various diseases and disorders (28, 5). This became even more pronounced with the strike of the pandemic especially in the younger generation (19, 20). HRV has proved to be a good clinical marker to echo these changes. On the other hand, various physical activity, aerobic exercises, mind body exercises have positively improved resilience to stress and enhanced the cardiac and brain health (2 , 16, 18, 29). HRV has been measured in several studies previously on adults but documented evidence on children is minimal (24, 26).

Karate is a martial art form which involves slow and fast intermittent physical activity along with rhythmical breathing. Encompassing different levels of cognitive ability, focused attention, memory and methods to reduce stress and cope with it (4). This research paper is an effort to investigate the effects of karate training on neuro-autonomic modulation through HRV analysis. This analysis measures consecutive time intervals between the adjacent heart beats (RR intervals) and inter-beat measurement differences (NN intervals) from the sinus source providing information about the autonomic tone. Karate practitioners are compared with age sex matched active controls to understand the insights of neurocognition through the analysis of HRV.

The purpose of the present observational study was to understand the impact of regular karate training towards cardiac autonomic function through Heart Rate Variability (HRV) analysis in the pediatric male population. To fulfil the purpose of the present study, the following objectives were elaborated:

a. To compare the dominance of karate training on brain functions among karate practitioners and age-sex matched active controls using HRV parameters.
b. To measure the effects of regular karate training on the time domain and frequency domain HRV measurements.
c. To examine Heart Rate Variability as a neuroautonomic tool to understand the mechanism underlying the benefits of neurocognition through parasympathetic and sympathetic dominance.

Table 1. Details of Time Domain and Frequency Domain Variables which comprise HRV Measurements.

Time Domain Variables	**Units**	**Description**	**Dominance**	**Time Measures**
SDNN	milli seconds (ms)	Inter-beat interval between successive heart beats	Parasympathetic dominance	Standard deviation of all NN intervals.
RMSSD	milli seconds (ms)	The square root of the mean of the sum of the squares of differences between adjacent inter beats.	Parasympathetic dominance	Square root of the mean of the squared differences between successive NN intervals
NN50 Count	numbers	Adjacent NN intervals differing by more than 50 msec in the entire recording.	Parasympathetic dominance	Number of adjacent NN intervals that differ from each other by more than 50 msec
PNN50	percentage %	The percentage of differences between successive NN intervals	Parasympathetic dominance	NN50 count divided by the total number of all NN intervals.
Frequency Domain Variables	**Units**	**Description**	**Dominance**	**Frequency Range**
VLF power	square milliseconds (ms^2)	Power in very low frequency range	Parasympathetic dominance	^0-04 Hz
LF power	square milliseconds (ms^2)	Power in low frequency range	Parasympathetic dominance	0-04-0-15 Hz
LF norm	n.u.	LF power in normalized units LF/ (Total Power-VLF) x 100	Sympathetic dominance	0.04–0.15 Hz
HF power	square milliseconds (ms^2)	Power in high frequency range	Parasympathetic dominance	0-15-0-4 Hz
HF norm	n.u.	HF power in normalized units HF/ (Total Power-VLF) x 100	Parasympathetic dominance	0-15-0-4 Hz
LF/HF	%	Ratio LF [ms^2]/HF [ms^2]	Sympathetic dominance	-

METHODS

Participants

The study was conducted at the Exercise and Sports Physiology Laboratory, Department of Physical Education, Jadavpur University, Kolkata, India. A power analysis was conducted with G*POWER 3.1.9.7 for Windows (2020) determined that 30 participants were needed in the present study for a power of 0.26, with an effect size of 0.5 and α=0.05. Thus, a total of 30 male school going subjects aged 8-12 years (n=30) were selected through convenient sampling method under two groups; the Karate group (K; n=15) and the Control group (C; n=15).

Inclusion and Exclusion Criteria: The karate group comprised of male practitioners with a training age of minimum three years (3±0.2years), practicing four days a week for one hour each day, at a reputed karate training organization, while age-sex matched children from reputed schools in Kolkata, who participated in unorganized play for similar duration formulated the control group. This detail was obtained through a simple survey conducted during the pre-data collection meetings with the entire subject population. Thus, sedentary children were excluded from the study. These criteria were strictly adhered to as the study intended to measure the training effect on these young children. This research study was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (23).

Protocol

The complete recording protocol followed the ethical guidelines for Biomedical Research on Human Participants (Minors) formulated by the Indian Council of Medical Research ICMR (2017) (10, 22). The protocol was explained to the minor subjects, on their verbal affirmation the informed consent forms were filled by their legal representatives. Independent Ethics Committee under the affiliation of Central Drugs Standard Control Organization (CDSCO), Ministry of Health and Family Welfare Government of India and the Institutional Ethics Committee for Human Research, Visva-Bharati approved the protocol. The study was also approved by Clinical Trial Registry of India (CTRI). Regn. No: CTRI/2021/06/034483.

The demographic variables were then measured, following which the subjects were rested in a quiescent and calm environment with a constant temperature of 27-30°c for around thirty minutes. The data was then extracted by placing each one comfortably in a chair using the RMS Polyrite (RMS, India), the polygraph was set and run for two minutes after which data was collected for five minutes. Any jewelry near the electrode sites was removed and mobile phones kept away from the participants. The skin was then cleaned with alcohol spirit at the standard lead placement regions after which electrode gel was put on the electrode sponge pads and then attached to the skin. The electrode impedance was checked for resistance and kept below 5 KΩ; surety was maintained that the leads are properly attached to the cables and the ECG amplifier and the data acquisition unit. Extracted data was checked for artefacts or noise and projected graphically on the RMS Physiograph D version 5.0.6. Five subjects were measured each day, after which the setting of the leads was checked. The data collection was carried out on two successive days and the best trial was taken for assessment. All the sessions were conducted in the morning before lunch between 8:00 am and 12:00 noon. The RMS Vagus HRV software, provided readings in its analysis report on both the time and the frequency axis to realize the cardio autonomic activity in the participants. Figure 1 provides the detailed Trail Profile with the particulars of the primary outcomes.

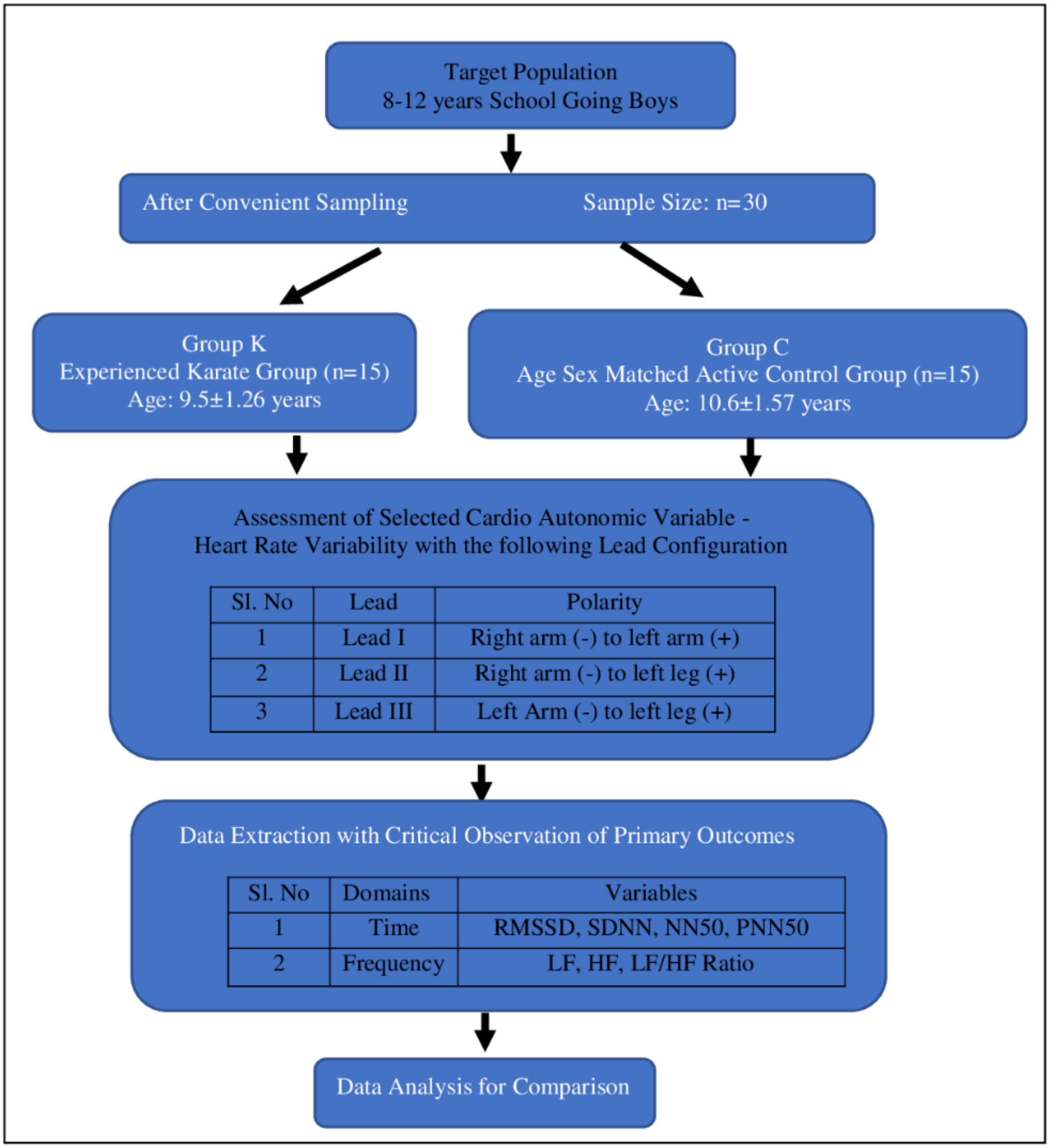

Figure 1. Trail Profiling with HRV Lead Configuration and Primary Outcome Classification.

Statistical Analysis

The Kolmogorov-Smirnov test was conducted to check the numerical normality and it was found that the data was normally distributed. Mean and standard deviation was performed as descriptive statistics, while time and frequency domain HRV variables were extracted using the independent two tailed t-test as inferential statistics. SPSS 20.0 software for Windows was used for the comparative analysis of the data. Measurement data were expressed as Mean±SD and the significance level was set at 0.05 ($P < 0.05$).

RESULTS

Descriptive statistics indicated the weight (34.50±5.04) and Body Mass Index (BMI) (18.53±1.20) of the Karate Group (k) to be significantly lower in comparison to the weight (49.20±9.69) and BMI (25.82±5.15) of the control group (c). Age and height showed no significant difference.
HRV measuring both time and frequency domains were compared among the two groups as shown in Table 2. The t-test showed significant results in the frequency domain parameters HF nu, LF nu and the LF/ HF ratio. The LF nu better known as the Low frequency power in normalized units was found to be significantly lower in the karate group (57.149±12.899 nu) than the control group (69.704±3.997) also, the LF/HF ratio in the karate group (1.536±0.773) was significantly lower than the active controls (2.354±0.453). This explains reduction in the sympathetic modulations in the Karate group. On the other hand, HF nu better known as the High frequency power in normalized units was measured to be significantly higher in the karate group (42.852±12.899nu) than in the control group (30.296±3.997nu) this explicates parasympathetic dominance in the karate practitioners ($P<0.05$). Results have been given below in Table 2.

Table 2. Comparison of the karate group and control group- descriptive and inferential statistics.

Comparison of the Karate Group and Control Group- Descriptive and Inferential Statistics									
Descriptive Statistics - A Comparison of the Karate Group and the Control Group									
Variables	**Groups**	**N**	**Mean & Std. Deviation**	**Std. Error Mean**	**df**	**Mean difference**	**St Error difference**	**t-ratio**	**Sig. (2 tailed) p value**
Age	**Karate Group**	15	9.50±1.27	0.4	28	1.1	0.64	1.72	0.103
	Control Group	15	10.60±1.58	0.5					
Height	**Karate Group**	15	136.20±8.66	2.74	28	1.9	3.16	0.6	0.555
	Control Group	15	138.10±4.95	1.57					
Weight	**Karate Group**	15	34.50±5.04	1.59	28	14.7	3.45	**4.26***	0
	Control Group	15	49.20±9.69	3.07					
BMI	**Karate Group**	15	18.53±1.20	0.38	28	7.29	1.67	**4.36***	0
	Karate Group	15	25.82±5.15	1.63					
Inferential Statistics - A Comparison of the Karate Group and the Control Group: Time Domain HRV Variables									
Min RR	**Karate Group**	15	0.796±0.172	0.054	28	0.064	0.063	1.016	.323
	Control Group	15	0.521±0.053	0.017					
Max/Min	**Karate Group**	15	1.591±0.163	0.051	28	0.074	0.080	0.917	.371
	Control Group	15	1.517±0.195	0.062					
Mean RR	**Karate Group**	15	0.678±0.082	0.026	28	0.042	0.043	0.976	.342
	Control Group	15	0.636±0.108	0.034					
Max HR	**Karate Group**	15	111.900±12.432	3.931	28	4.500	5.276	0.853	.405
	Control Group	15	116.400±11.128	3.519					
Min HR	**Karate Group**	15	70.800±8.804	2.784	28	7.700	5.745	1.340	.197
	Control Group	15	78.500±15.890	5.025					
Mean HR	**Karate Group**	15	89.700±11.206	3.544	28	7.100	6.112	1.162	.261
	Control Group	15	96.800±8.804	4.980					

SDNN	**Karate Group**	15	59.196±23.060	7.292	28	11.570	10.485	1.103	.284
	Control Group	15	47.626±23.825	7.534					
RMSSD	**Karate Group**	15	39.907±11.623	3.676	28	8.097	6.500	1.246	.229
	Control Group	15	31.810±16.955	5.362					
NN50	**Karate Group**	15	89.800±64.480	20.391	28	27.900	28.563	0.977	.342
	Control Group	15	61.900±63.250	20.001					
pNN50	**Karate Group**	15	25.940±16.302	5.155	28	9.310	8.061	1.155	.263
	Control Group	15	16.630±19.598	6.197					

Continuation of Table 2. Comparison of the karate group and control group- descriptive and inferential statistics.

Inferential Statistics - A Comparison of the Karate Group and the Control Group: Frequency Domain HRV Variable									
VLF	**Karate Group**	15	54.576±22.381	7.078	28	2.864	9.884	0.290	.775
	Control Group	15	57.441±21.818	6.899					
VLF ms²	**Karate Group**	15	485.163±488.485	154.472	28	190.708	317.274	0.601	.555
	Control Group	15	675.871±876.364	277.131					
LF Power	**Karate Group**	15	23.995±11.012	3.482	28	5.918	6.105	0.969	.345
	Control Group	15	29.913±15.857	5.014					
LF nu	**Karate Group**	15	57.149±12.899	4.079	28	12.555	4.270	**2.940***	.009
	Control Group	15	69.704±3.997	1.264					
LF ms²	**Karate Group**	15	172.481±130.167	41.162	28	53.536	71.783	0.746	.465
	Control Group	15	226.017±185.968	58.808					
HF Power	**Karate Group**	15	21.429±13.246	4.189	28	8.782	4.666	1.882	.076
	Control Group	15	12.646±6.501	2.056					
HF nu	**Karate Group**	15	42.852±12.899	4.079	28	12.555	4.270	**2.940***	.009
	Control Group	15	30.296±3.997	1.264					
HF ms²	**Karate Group**	15	133.914±102.383	32.376	28	37.640	40.346	0.933	.363
	Control Group	15	96.274±76.127	24.073					
LF/HF	**Karate Group**	15	1.536±0.773	0.245	28	0.818	0.283	**2.886***	.010
	Control Group	15	2.354±0.453	0.143					

DISCUSSION

Physical activity positively influences heart rate variability and helps in reduction of stress for all age groups for the general population. The documented evidence of higher heart rate variability and stable autonomic innervations have been reported for the elderly and general adult community (12, 25). However, such studies on children and adolescents are restricted and around a score of studies were found in the past decade (7).

Karate is a kind of physical activity which influences the mind and the body through its slow and fast intermittent movements and synchronized breathing pattern. Moreover, in this pandemic situation sedentary routine has become a lifestyle especially among the younger generation having to stay indoors for safety. When all other physical activity is restricted karate is one such practice which can be continued even in home isolation. Moderate intensity actions with rhythmical breath control and mental focusing through concentration development qualify this art form as a mind body practice to maintain physical and mental health.

HRV profiling has steadily evolved into an application tool in sports training and athletic conditioning (14, 8, 15). The shift from sympathetic to the vagal tone in various types of athletes have been researched on, but interestingly very few studies in the area of martial art have been reported on the same lines, (9, 26) with one on judo, jujitsu and mixed martial art (27, 21, 6). The judo, jujitsu and mixed martial art players in these three studies were between an age range of 18-45 years. Judo players were made to perform a strength training program for four weeks, mixed martial art players on the other hand were professionals and all jujitsu players had graduated from the white to black belt thus were experienced; no exercise intervention was incorporated on them. The present study is a first time attempt where long-term karate training has been considered an intervention as a comparative model among school going children. The mechanism indicative of such results has been shown in Figure 2.

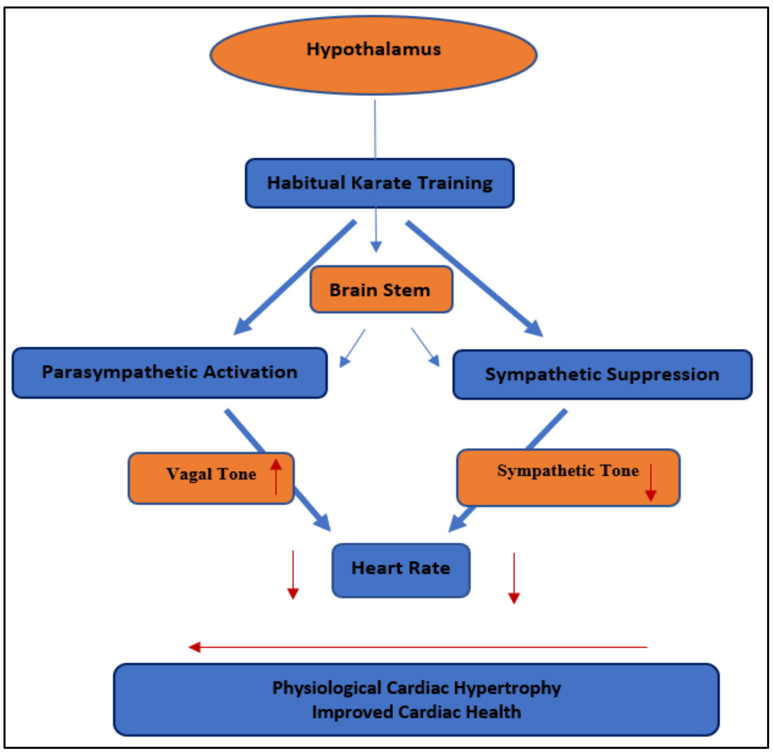

Figure 2. Dynamic Cardio Autonomic Relationship with Habitual Karate Training.

Hence, the present study intended to identify the effects of karate exercise and training on the young population as a habitual training. Previous research work on the immediate effects of karate exercise by the authors highlighted increase in heart rate and sympathetic systemic changes in the body (3). In the current study regular karate training of three years or more has been investigated and shown to produce prominent vagal tone. The parasympathetic dominance also significantly increased as seen through HRV quantification in the frequency domain parameters HF nu, LF nu and the LF/ HF ratio evident through the statistical results of the study. While time domain aspects RMSS, SDNN and NN50 all showed positive improvement reflecting parasympathetic dominance in the karate group.

In fact, this research paper also clearly indicates a very pertinent aspect through its results, the active control group indulged in unorganized play for similar hours as the karate practitioners practiced their training protocols, nevertheless the BMI of the control group were significantly higher and so was their weight, which may indicate that there is a difference between a leisure play mind-set and a karate growth mind-set which may have caused this difference.

The findings in the present study through short term HRV time and frequency domain measurements clearly explain the intervention being provided to the karate practitioners strongly maintains a dynamic homeostasis between the stress, autonomic adaptations and cardiac fitness.

Positive and significant relations have been drawn within the limitations of this research study; between long term karate training and cardio autonomic modulation with HRV as the measurement tool. The physical activity comparison among both the groups could be quantified, to realize energy expenditure in the future. The study clearly signifies that simple karate movements through regular practice with very few requirements in terms of space and equipment, can do wonders to optimize cardiovascular fitness and autonomic functioning. Attention and focus are developed through this art form, not just to optimize oneself in a stressful environment but also to maintain a better psychophysiological homeostasis. However, the present study involved children with a training age of three years to the maximum, it could yield even better results among elite karate practitioners with a longer training span.

ACKNOWLEDGEMENTS

We would like to acknowledge University Grants Commission (UGC) and Jadavpur University for permitting the Departmental Grant RUSA 2.0 for upgradation of our laboratory equipment which eased out the data collection process.

It is worthy to acknowledge all the children, their parents, karate organizations and the schools for providing the necessary consent for making this research possible during the pandemic condition. There is no funding whatsoever for this research.

REFERENCES

1. Alderman BL, Olson RL. The relation of aerobic fitness to cognitive control and heart rate variability: A neurovisceral integration study. Biol Psychol 99: 26-33, 2014.

2. Aubert AE, Seps B, Beckers F. Heart rate variability in athletes. Sports Med 33(12): 889- 919, 2003.

3. Bhattacharya P, Chatterjee S. Immediate effect of single bout of karate exercise on heart rate. Available from: M. Hassan et al. [eds.], Enhancing Health and Sports Performance by design. MoHE 2019. Lecture Notes in Bioengineering Singapore: Springer; 2020.

4. Bhattacharya P, Chatterjee S, Mondal S. Stress induced changes in neurotrophic mechanism and mind set of martial art practitioners: A systematic review. Ido Movement for Culture. J Martial Arts Anthropol 21(4): 64-74, 2021.

5. Bustamante-Sanchez A, Tornero-Aguilera JF, Fernandez-Elias VE, Hormeño-Holgado AJ, Dalamitros AA, Clemente-Suárez VJ. Effect of stress on autonomic and cardiovascular systems in military population: A systematic review. Cardiol Res Pract 2020: 7986249, 2020.

6. Coyne JOC, Coutts AJ, Fomin R, French DN, Newton RU, Haff GG. Heart rate variability and direct current measurement characteristics in professional mixed martial arts athletes. Sports (Basel) 8(8): 109, 2020.

7. Chen H, Xu J, Xie H, Huang Y, Shen X, Xu F. Effects of physical activity on heart rate variability in children and adolescents: A systematic review and meta-analysis. Cien Saude Colet 27(5): 1827-1842, 2022.

8. Djaoui L, Haddad M, Chamari K, Dellal A. Monitoring training load and fatigue in soccer players with physiological markers. Physiol Behav 181: 86-94, 2017. [published correction appears in Physiol Behav 194: 589, 2018]

9. Dong JG. The role of heart rate variability in sports physiology. Exp Ther Med 11: 1531-1536, 2016.

10. Ethical guidelines for biomedical research on human participants. Available from: https://www.icmr.nic.in/ethical_guidelines.pdf; 2006.

11. Forte G, Favieri F, Casagrande M. Heart rate variability and cognitive function: A systematic review. Front Neurosci 13: 710, 2019.

12. Grässler B, Thielmann B, Böckelmann I, Hökelmann A. Effects of different exercise interventions on heart rate variability and cardiovascular health factors in older adults: A systematic review. Eur Rev Aging Phys Act. 18(1): 24, 2021.

13. Hon EH, Lee ST. Electronic evaluation of the foetal heart rate. VIII. Patterns preceding foetal death, further observations. Am J Obstet Gynecol 87: 814-826, 1965.

14. Kayacan Y, Yildiz S. Resting and post exercise heart rate variability in professional handball players. J Sports Med Phys Fitness 56(3): 302-310, 2016.

15. Kiviniemi AM, Hautala AJ, Kinnunen H, Nissilä J, Virtanen P, Karjalainen J, Tulppo MP. Daily exercise prescription on the basis of HR variability among men and women. Med Sci Sports Exerc 42(7): 1355-1363, 2010.

16. Leicht AS, Allen GD. Moderate-term reproducibility of heart rate variability during rest and light to moderate exercise in children. Braz J Med Biol Res 41(7): 627-633, 2008.

17. Luque-Casado A, Zabala M, Morales E, Mateo-March M, Sanabria D. Cognitive performance and heart rate variability: The influence of fitness level. PLoS One 8(2): e56935, 2003.

18. Lu WA, Kuo CD. Comparison of the effects of Tai Chi Chuan and Wai Tan Kung exercises on autonomic nervous system modulation and on hemodynamics in elder adults. Am J Chin Med 34(6): 959-968, 2006.

19. Marques de Miranda D, da Silva Athanasio B, Sena Oliveira AC, Simoes-E-Silva AC. How is COVID-19 pandemic impacting mental health of children and adolescents? Int J Disaster Risk Reduct 51: 101845, 2020.

20. Meherali S, Punjani N, Louie-Poon S, Rahim KA, Das JK, Salam RA, et al. Mental health of children and adolescents amidst COVID-19 and past pandemics: A rapid systematic review. Int J Environ Res Public Health 18(7): 3432, 2021.

21. Morales J, Alamo JM, García-Massó X, Buscà B, López JL, Serra-Añó P, et al. Use of heart rate variability in monitoring stress and recovery in judo athletes. J Strength Cond Res 28(7): 1896-1905, 2014.

22. National Ethical Guidelines for Bio-Medical Research Involving Children. Available from: https://www.icmr.nic.in; nd.

23. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

24. Ramos C, de Franca E, Nobre T, Santana J, Madureira D, Zocoler C, et al. Qi gong and heart rate variability: A systematic review. J Biosci Med (5)3: 120-127, 2017

25. Schuit AJ, van Amelsvoort LG, Verheij TC, Rijneke RD, Maan AC, Swenne CA, et al. Exercise training and heart rate variability in older people. Med Sci Sports Exerc 31(6): 816-821, 1999.

26. Suetake VYB, Franchini E, Saraiva BTC, da Silva AKF, Bernardo AFB, Gomes RL, et al. Effects of 9 months of martial arts training on cardiac autonomic modulation in healthy children and adolescents. Pediatr Exerc Sci 30(4): 487-494, 2017.

27. Tonani ECF, Fernandes EV, Dos Santos Jr RB, Weber MG, Andreato LV, Branco BHM, et al. Association of heart rate and heart rate variability with an anaerobic performance test and recovery of Brazilian jiu-jitsu athletes. Int J Perform Anal Sport 21(3): 361-373, 2021.

28. Tsigos C, Kyrou I, Kassi E, Chrousos GP. Stress: Endocrine physiology and pathophysiology. Available from: Feingold KR, Anawalt B, Boyce A, et al, eds. Endotext. South Dartmouth, MA: MDText.com, Inc; 2020.

29. Tyagi A, Cohen M. Yoga and heart rate variability: A comprehensive review of the literature. Int J Yoga 9(2): 97-113, 2016.