BALTIC JOURNAL OF SPORT & HEALTH SCIENCES
No. 1(124); 2022; 40–48; ISSN 2351-6496 / eISSN 2538-8347
DOI: https://doi.org/10.33607/bjshs.v1i124.1163

The Comparison of Heart Rate Variability and Energy Expenditure of Chess Players between a Chess Game and Physical Activity

Coskun Rodoplu, Ramiz Arabacı, Recep Gorgulu
Bursa Uludag University, Bursa, Turkey

ABSTRACT

Background. A game of chess represents a legitimate physical and psychological stress due to its strategic and cognitively demanding nature over a long period of time. This very challenging situation has not been thoroughly explored and, to the best of our knowledge, there is no research report that has concentrated on both heart rate variability and energy expenditure for deeper understanding of chess players' performance. The main aim of the present study was to examine the HRV and EE of chess players before, during and after a competition, as well as the moderate level of running exercise.

Methods. The sample comprised 24 (19 men, 5 women; Mage=24.8) volunteer chess players who have been playing chess regularly for at least 5 years. The average National Chess Rating (NCR) of participants was determined as 1526. In addition, a total of ten participants have International Chess Rating (ELO) rating (mean = 1588). We obtained participants' body mass indexes before the experiment took place. Participants' HR and HRV were taken through the chess competition, and running exercises took place in 3 different time periods; before (15 min), during (30 min) and after (15 min).

Results. Our results indicated that there was a significant difference on HRV between chess competition and running exercises HRV (RMSSD, SDNN, NN50 and RR) (p=.001). Besides, there was a significant difference on participants' EE between a chess competition and a moderate level of running (p=.001).

Conclusions. HRV values determined in chess competition and running exercise are different from each other. Contradictory to our speculative hypothesis, the current results provide that a moderate level of running exercises requires more energy expenditure than a chess game.

Keywords: running exercise, mental activity, autonomic nervous system, parasympathetic activity.

INTRODUCTION

Chess is one of the most competitive strategy board games in the world, requiring a large amount of practice for optimal performance (Moen, Olsen, & Hrozanova, 2020; Yen, Yang, & Hsu, 2004). Furthermore, chess players face intensive pressure due to the competitive nature of the chess game, especially before and during a competition (Fuentes-Garcia, et al., 2019). The influence that physical and psychological pressure exerts on performance continues to be a major area of interest for many researchers (Gorgulu, Cooke, & Woodman, 2019; Lautenbach et al., 2016; Woodman & Hardy, 2003). However, the optimal level of physical and psychological performance of chess players is still unknown.

One variable that can monitor both psychological and physical indexes of chess players is heart rate variability (HRV). HRV corresponds to a measure of the variation in duration between each heartbeat over time (Thayer et al., 2012) that can serve as the variability of the N–N intervals which is considered a quantitative marker for assessing adequate cardiac regulation by the autonomic nervous system as a response to both physical and psychological stimuli (Cancino, 2011; Dong, 2016). Moreover, the HRV has been considered as a measure of heart-brain interaction (Shaffer, McCraty, & Zerr, 2014). HRV can be reduced before situations that generate levels of stress (Miu et al., 2009), which is inevitable during chess competition where players' decisions determine the matter of winning or losing. HRV is a highly applicable tool to control and monitor workload in chess players (Fuentes et al., 2019; Villafaina et al., 2019) and it can be analysed in the time, frequency and non-linear domains. Analysis of HRV is widely used as a standard method for assessing autonomic nervous functions. Particularly, low-frequency (LF, 0.04–0.15 Hz) and high-frequency (HF, 0.15–0.4 Hz) spectral components of HRV are used as the separate metrics of sympathetic and parasympathetic (vagal) functions (Appel et al., 1989; Camm et al., 1996).

Another variable that can affect chess players' performance is energy expenditure (EE), especially depending on the length of the competition. Activity-induced energy expenditure is the most variable component of daily energy expenditure, as determined by the activity pattern including exercise (Westerterp, 2018). Energy expenditure during locomotion varies 10–15% between individuals of similar body mass (Hunter et al., 2004), thus activity related energy expenditure and volume of physical activity are different entities, although highly related (Hunter et al., 2013). Energy cost of physical activity is the most variable component of total daily energy expenditure that accounts for energy consumed by spontaneous and voluntary exercise (Lam & Ravussin, 2016). In a competitive chess game, players have to think through a wide range of move sequences to find the best choice; that is a very challenging and interesting situation which requires a great deal of mental effort. Mental effort induces the mobilisation of energy for cognitive purposes and induces a compensatory strategy to protect performance in the presence of augmented request tasks (Gaillard, 1993; 2001). Therefore, glucose is used as a primary fuel for energy generation in the brain during mental effort (Rao et al., 2006; Fairclough & Houston, 2004) such as a chess game. However, although there is a great body of evidence regarding metabolism during mental as well as physical activity in the literature (Troubat et al., 2008), in terms of providing specific information for chess players further investigation would provide more comprehensive information in the relevant area of research (Fuentes-Garcia, et al., 2019).

Heart rate (HR) values are one of the valid and reliable methods in estimating energy expenditure (Hiilloskorpi et al., 2003). Additionally, it has been emphasised that HR and HRV parameters may be associated not only during physical activity (Arabaci, Pehlivan, & Gorgulu, 2020) but also some psychological parameters such as stress, state anxiety (Barlow et al., 2016: Gorgulu et al., 2019; Murray and Raedeke, 2008) that can be experienced by chess players at any level. Besides, standard methodologies of cardiac activity analysis and physiological interpretation as a marker of autonomic nervous system condition have been largely published, but not so much during a chess game. Furthermore, HRV was reduced in participants who achieved worse results in cognitive tasks, which could indicate the possibility of HRV predicting cognitive performance (Muthukrishnan et al., 2017), such as under a high cognitive load (e.g. pressure) chess game.

Therefore, our aim of the current study is to investigate the HR and HRV as well as the energy expenditure of chess players during a competitive chess game and low-to moderate level of physical activity, namely running. More specifically, we hypothesised that there would be no significant difference on HR, HRV and EE whether during a competitive a chess game or a low-to moderate level of running exercise.

METHODS

Participants

The sample comprised twenty-four (male, n = 19 and female, n = 5) volunteer participants between the ages of 18–40 who have been playing chess regularly for at least 5 years. The inclusion criteria were that volunteers have an average National Chess Rating (NCR) of 1526 points. In addition, a total of ten participants have an International Chess Rating (ELO) rating (mean = 1588). According to the physical activity readiness questionnaire (PAR-Q), healthy volunteers were included in the study. Participants with any health problems in the cardiovascular, digestive or respiratory system, used addictive substances such as cigarettes, alcohol and drugs that affected mental and physical performance were not included in the current study. The study was conducted in accordance with the Helsinki Declaration, and was approved by the Ethics Committee of the Faculty of Medicine, Bursa Uludag University (16 December 2019, and numbered 2019–20/15).

G*Power 3.1 (Düsseldorf, Germany; Faul, Erdfelder, Buchner, & Lang, 2013) calculation software indicated that by adopting an alpha of .05 and a sample size of 24, the experiment was powered at .80 to detect significant differences between conditions for effect sizes exceeding f = .20 (i.e., small to medium size effects) by One Way Analysis of Variance (ANOVA; Cohen, 1992). Although there are limited previous data on which to base these calculations, Fuentes-Garcia et al.'s (2019) test of on adolescent chess players, adopting a similar design with non-parametric Mann Whitney U test, revealed large within-subject effects (*N=14.1; p-value < 0.05*).

Experimental procedures

HR, HRV measurements and energy expenditure of participants were determined in 3 different time periods (15 minutes before, 30 minutes during and 15 minutes after) during the chess game and running exercise (see figure 1). To better understand the effect of HRV on recovery response, HRV recordings were obtained before and after 15 minutes of the experiment.

On first arrival at the test site, the experimenter informed each participant and asked them to complete the personal information sheet that includes such demographic information as age, sex, weight, and years of experience in chess; BMI was also measured. Then they were matched with each other, based on their ELO points, to create a competitive chess game. Their HR and HRV were analysed for 15 minutes before, 30 minutes during and 15 minutes after the chess game. The official chess clock (Schach Queen E410) was used for timing during the chess game.

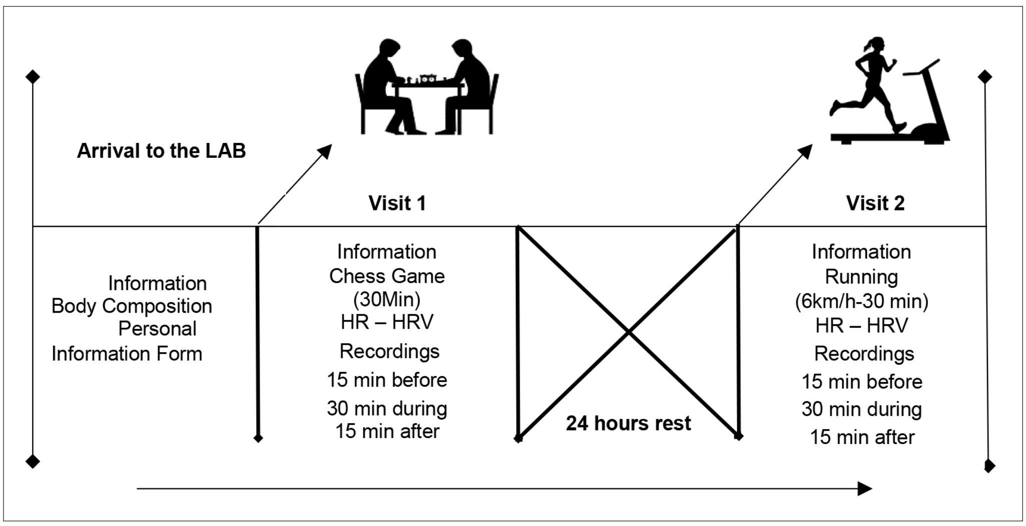
On the second arrival at the test site, the experimenter informed the participants about the procedure and asked them to complete the Physical Activity Readiness Questionnaire (PARQ). HR and HRV were recorded using a Polar V800 heart rate monitor with the Polar H7 chest strap. Participants were then asked to run for 30 minutes on the treadmill at a speed of 6 km/h .

Measurements

Body Composition: Height of the participants was measured using the Mesitas height meter (Germany) device. Body composition was analysed with TANITA BC-418MA (Japan) Segmental Body Analysis Monitor. The device was analysed for total body weight, body mass index (BMI), basal Metabolic Rate (BMR-kcal), impedance (ohms), fat rate (%), fat amount (kg), lean mass (kg) and total body fluid (kg).

Heart Rate (HR) and Heart Rate Variability (HRV): in the current study HR, HRV and EE was measured with a Polar V800 (Polar Electro, Kempele, Finland) monitor with the compatible chest strap of a Polar H7 transmitter. Heart rate variability measures were calculated and this dataset normalised by adopting artefact correction

Figure 1. **Demonstration of the experimental design**



methodology using Kubios HRV 2.0 (Tarvainen et al., 2014). Research in sports science has also been marked by the use of heart rate and heart rate variability (HRV) to non-invasively assess the activity of the autonomic nervous system (ANS) and to monitor the possible states of a training process (Baumert et al., 2006). HRV corresponds to the changes in time between consecutive R-R intervals, has been associated with good adaptability, and indicates well-functioning autonomic control mechanisms.

Physical Activity Readiness Questionnaire: A test was applied to understand that the participants in the research were physically healthy. This test consists of 7 questions and will allow athletes to participate in the research without any health check. In the study, it was applied to the participants before physical activity.

Statistical analyses

The data were analysed with SPSS in Windows 26.0 (SPSS Inc, Chicago, USA) statistics program. The Shapiro Wilk Test was used to verify the normality of data. One-Way ANOVA was used to compare the data obtained before, during and after the experiments separately (chess game and physical activity). The Bonferroni test was used in binary comparisons. Across two different measurements on visits 1 and 2, the comparison of the differences in HRV and energy expenditures was analysed with Two Way ANOVA. Cohen's *d* impact dimensions were calculated to compare the magnitude of the difference between the groups. Hopkins' criteria were applied to interpret the effect size: <.2 trivial, 0.2-0.5 small, 0.6-1.1 moderate, 1.2-1.9 large and 2.0-4.0 very large. The level of significance was set at $p < .05$.

RESULTS

Descriptive statistics of the participants were shown in Table 1. The data obtained in two occasions, chess competition and running exercise, time-domain, frequency-domain, non-linear measurement HRV parameters and the amount of energy expenditure were analysed accordingly.

There was a significant difference on participants' heart rate variability based on the time domain analysis of HRV parameters namely RR (η^2= .575), RMSSD (η^2=.191), SDNN (η^2=.287), NN50 (η^2=.246) values between chess competition and running exercises. Therefore, participants' heart rate variability indices were lower during physical activity than playing chess (p<.001).

In frequency-domain analysis, for instance PNN50 (η^2=.246) was lower during chess playing than physical activity (p<.002). In line with that, other HRV frequency domain indices were significantly lower during physical activity HF*log* (η^2=.449), LF*log* (η^2=.527), VLF*log* (η^2=.395) than playing chess respectively (p<.001).

In addition to the above results, non-linear measurement parameters for HRV, participants' SD1 (η^2=.162) and SD2 (η^2=.273) were found significantly lower during physical activity than playing chess (p<.001). Lastly, a significant difference was found in energy expenditure (before, during, and after) of chess competition and running exercise, therefore, participants' energy expenditures were higher (EE, η^2=.557) than in playing chess (p<.001).

Table 1. **Descriptive statistics of the participants**

Variable	Mean	SD	Min	Max
Age *(year)*	24.8	4.7	19	40
Weight *(kg)*	75.9	15.5	45	107
Height *(cm)*	175.2	7	164	186
BMI *(kg/m²)*	24.1	5.65	5.6	33.7
BMR*(kcal)*	1848	311.4	1141	2318
TBF *(%)*	17.4	7.7	3.6	31.3
FM *(kg)*	13.7	7.5	2.3	30.5
FFM *(kg)*	60.8	10.8	36.6	76.9
TBW *(kg)*	45.5	7.9	26.8	56.3

Note: kg: kilograms; cm: centimeter; kcal: kilocalories; s: seconds; min: minimum; max: maximum; SD: standard deviation; bmı: body mass index; bmr: basal metabolic rate; tbf: total body fat; fm: fat mass; ffm: fat free mass.

DISCUSSION AND CONCLUSION

The aim of this study was to examine the HRV and energy expenditure of chess players before, during and after both a competition and a moderate level of physical activity. Most of the studies conducted to date have focused on the examination of the HRV values related solely to physical activity (Hottenrott, Hoos, & Esperer, 2006; Chen et al., 2011; Aras, Akca, & Akalan, 2014). Besides, information about HRV changes during the chess game is not sufficient to date. Therefore, we hypothesised that there would be no significant difference on HR, HRV and EE whether during a competitive chess game or low-to moderate level of running exercise accordingly.

Conversely, our results revealed that there was a significant difference in both HRV and energy expenditure values of chess players obtained during chess competition and moderate level of running exercise. Comparatively, HRV time-domain parameters (SDNN, RMSSD) were lower in the running exercise than a chess competition. Furthermore, the amount of energy expenditure in running exercise was higher than the chess competition.

In sport sciences, HRV analyses are used to assess the acute or chronic physiological effects of exercise, and the responses obtained here were accepted as an important parameter in the autonomous regulation of the heart despite the genetic differences (Kaikkonen, et al. 2008; Chen et al., 2011; Aras, Akca, & Akalan, 2014). In a study conducted on adults, the values taken 30 minutes and 24 hours after the 1 hour running exercise were significantly higher than before the running exercises (Aras, Karakoc, & Koz, 2014). In a seminal study, HRV values were found to decrease due to increased exercise intensity (Hunt et al., 2018). In other words, the decrease in HRV values may be interpreted as an indicator of increased severity and fatigue (Baumert et al., 2006; Hottenrott, Hoos, & Esperer, 2006). Our results provided support for this notion that HRV was lower during moderate level of physical activity to compare before and after.

On the other hand, cognitive load in a chess game or competition has a significant effect on HR and HRV (Troubat et al., 2008; Ates et al., 2017). In a study examining HRV values in a chess game, it was revealed that the values during the chess game decreased compared with the pre-game values (Fuentes et al., 2019). These results provided that there is a relationship between HRV and the mental state of a chess player.

As a result of the analysis of time and frequency domain parameters, when the mental activity and resting state were compared, it was determined that the mean RR interval was lower and the pNN50 value was higher while at rest (Uysal & Tokmakci, 2017). According to another study, HRV revealed significant differences in nonlinear parameters (SD1, SD2). These HRV parameters may indicate that changes caused by mental processes may be more susceptible than others. In line with our results, time domain and nonlinear measurements emerged as reliable and sensitive mental effort indices (Mukherjee et al., 2011). In these complex dynamic systems, nonlinear analysis parameters can give a sufficient idea (Goldberger, 1996). It may strengthen the suitability of HRV to be used to monitor and control the mental effort of chess players before, during and even after a chess competition.

According to other previous research results (Troubat et al., 2008), it was determined that there was a significant increase in heart rate variability at the beginning of the competition remaining high until the end of the game. Significant increases in both LF and LF/HF ratio and a significant decrease in mean RR were also observed. Similar results were found from the current research. For example, RR, RMSSD, SDNN and HF values before a chess competition was significantly lower than after the chess competition. According to these findings, we can conclude that before the competition, stress and excitement levels of the participants were usually higher (Sloan, 1994; Dishman et al., 2000) causing a significant change in HRV parameters.

Although there is no physical activity required during a chess game, there would be a significant decrease in HRV due to such psychological factors as cognitive load, stress, anxiety and excitement (Luque-Casado et al., 2013). Therefore, these findings do not support our hypothesis that HRV values during chess competition and continuous running exercise would be similar. Especially, it has been established that although chess players experience no physical activity during the chess competition, they spend a significant amount of calories with cognitive load (Troubat et al., 2008). Moreover, grandmasters are constantly exposed to mental stress, which causes increased heartbeat. In our study, HR values before chess were higher than the passive resting period after competition (see Table 2): this is due to the sympathetic nervous

Table 2. **Heart rate variability parameters and energy expenditure values of chess competition and running exercise**

Variable		Pre-test	Test	Post-test	F	*p*	η^2	Cohen's *d*
		Mean ± *SD*	Mean ± *SD*	Mean ± *SD*				
HR *(bpm)*	**CE**	86 ± 11	89.8 ± 15.3	82.4 ± 10.9	64.097	.001	.708	3.11[ııı]
	RE	79.7 ± 9.7	118.7 ± 19.5	86.6 ± 13.5				
RR *(ms)*	**CE**	709.5 ± 99.7	686.8 ± 124.7	744.6 ± 105.9	62.240	.001	.575	2.32[ııı]
	RE	763.4 ± 96.8	518 ± 84.5	711.5 ± 125.9				
SDNN *(ms)*	**CE**	47.4 ± 14.8	39.8 ± 14.3	50.2 ± 14.9	18.504	.001	.287	1.26[ııı]
	RE	48.1 ± 13.5	14.8 ± 8.2	49.9 ± 22.5				
RMSSD *(ms)*	**CE**	31.1 ± 11.5	30.2 ± 17.6	33.9 ± 13	10.834	.001	.191	0.97[ııı]
	RE	33.6 ± 13.2	11.7 ± 7.8	36.5 ± 27.6				
NN50 *(beats)*	**CE**	130.5 ± 99.4	226.2 ± 219	146.6 ± 109.7	14.993	.001	.246	1.14[ııı]
	RE	147.2 ± 111.9	25.1 ± 35	124.6 ± 116.2				
PNN50 *(%)*	**CE**	11.3 ± 8.9	9.6 ± 9.6	13.1 ± 10.9	6.574	.002	.125	0.75[ııı]
	RE	13.3 ± 11	0.8 ± 1.2	11.2 ± 11.2				
RR TRAINGULAR-INDEX	**CE**	12 ± 3.3	10.6 ± 4.2	13.3 ± 4.4	23.833	.001	.341	1.43[ııı]
	RE	12.5 ± 3	3.6 ± 2.9	11.2 ± 3.8				
TINN *(ms)*	**CE**	263.4 ± 82	259.1 ± 88.2	270.7 ± 73.1	6.683	.002	.127	0.76[ııı]
	RE	262.2 ± 73	169.4 ± 106.9	274.9 ± 120.4				
VLF *(log)*	**CE**	4.9 ± 0.6	4.4 ± 0.9	4.8 ± 1	30.021	.001	.395	1.61[ııı]
	RE	5 ± 0.6	2.5 ± 1	4.7 ± 0.5				
LF *(log)*	**CE**	7.1 ± 0.6	6.6 ± 0.9	7.3 ± 0.5	41.314	.001	.527	2.11[ııı]
	RE	7.3 ± 0.5	4.4 ± 1.2	7.2 ± 0.7				
HF *(log)*	**CE**	5.8 ± 0.7	5.5± 1.3	5.9 ± 0.7	50.743	.001	.449	2.10[ııı]
	RE	6.1 ± 0.7	2.8 ± 1.3	5.7 ± 1				
SD1 *(ms)*	**CE**	25.1 ± 12.4	21.3 ± 12.4	24 ± 9.2	8.877	.001	.162	0.87[ııı]
	RE	24.6 ± 9.6	8.3 ± 5.5	25.8 ± 19.5				
SD2 *(ms)*	**CE**	61.8 ± 18.9	51.7 ± 17.4	66.7 ± 19.5	17.241	.001	.273	1.22[ııı]
	RE	59.1 ± 16.9	19.1 ± 10.5	64.7 ± 26.8				
SD2/SD1	**CE**	2.6 ± 0.8	2.7 ± 0.7	2.7 ± 0.6	1.260	.288	.027	0.33[ı]
	RE	2.7 ± 0.5	2.5 ± 0.7	2.9 ± 0.8				
PNS INDEX	**CE**	-1.2 ± 0.7	-1.3 ± 1.1	-1.1 ± 0.8	37.332	.001	.448	1.80[ııı]
	RE	-0.9 ± 0.8	-2.9 ± 0.7	-1.1 ± 1.2				
SNS INDEX	**CE**	1.4 ± 1	1.8 ± 1.6	1.1 ± 0.9	67.304	.001	.594	2.41[ııı]
	RE	0.9 ± 0.9	5.9 ± 2.7	1.5 ± 1.3				
EE *(kcal)*	**CE**	66.5 ± 23.7	156.8 ± 65	59.2 ± 22.2	57.736	.001	.557	2.24[ııı]
	RE	53.7 ± 21	282.9 ± 82.7	67.3 ± 31.4				

Note: CE:Chess Exercise; RE:Running Exercise; pretest: 15 minutes before exercise; test: 30 minute During exercise; posttest: 15 minutes after exercise; SD: standard deviation ; RR: time between RR intervals in milliseconds; SDNN: standard deviation of all normal to normal RR intervals RMSSD: root mean square of successive RR interval differences; NN50: number of successive RR interval pairs that differ more than 50 msec; pNN50: the percentage of intervals >50 ms different from preceding interval; Triangularindex: The integral of the RR interval histogram divided by the height of the histogram; TINN: Baseline width of the RR interval histogram; VLF: very low frequency ; LF: low frequency ; HF: high frequency; SD1: In Poincaré plot, the standard deviation perpendicular to the line-of-identity; SD2: In Poincaré plot, the standard deviation along the line-of-identity; SD2/SD1: Ratio between SD2 and SD1; PNS INDEX: Parasympathetic nervous system activity compared to normal resting value; SNS INDEX: Sympathetic nervous system activity compared to normal resting value; EE: energy expenditure; η^2:effect size; d: Cohen's effect size(effect size: [ı] small effect, [ıı] intermediate effect, [ııı] large effect).

system being activated while blood pressure increases and the heart speeds up. The brain uses glucose as the primary energy source (Maughan et al., 2010; Herculano-Houzel, 2011). It can be concluded that glucose is used as the energy source due to the increase in mental activity during a chess match.

Limited research done earlier showed how much energy players spent during the game (The grandmaster diet, 2013). In our study, we found calorie expenditure during chess competition (156.8 ± 65 kcal) and during running exercise (282.9 ± 82.7 kcal) were significantly different from each other, simply due to the overload effect of skeletal muscles during exercise.

There are certain limitations in the current study that need to be mentioned: first, the sample size is too limited to generalise the present findings; gender equality especially should be taken into consideration for future research. In addition to this, chess players with higher ELO scores should be recruited to see expertise differences on energy expenditure and changes in HRV while playing chess and doing a moderate level of exercise. In the present study, one of the most essential limitations is that we were unable to test participants' O2 capacity, and therefore used an adjusted individualised level of O2 capacity during physical activity on the treadmill. Thus, we standardised the level of running on the treadmill for each participant at the level of 6 km/h speed that needs to improve by adjusting this at the certain percentage of personalised O2 capacity for example %60–70 that associated with relevant physical activity.

In conclusion, HRV values determined in chess competition and running exercise are different from each other. Chess game HRV values were higher than running exercise values in the present study. Hereafter, future studies should try to examine and develop strategies to detect the precise point at which the load will induce individuals' psychophysiological breakdown linked to changes in HRV and energy expenditure of elite chess players.

Acknowledgements

This study was supported by the Scientific Research Projects Unit of Bursa Uludağ University [KOAP (SBF) -2020/11].

Authors would like to thank Dr. Bilal Bingölbali for his support during the data collection procedure in order to recruit participants. There is no conflict of interest in this research.

REFERENCES

Appel, M. L., Berger, R. D., Saul, J. P., Smith, J. M., & Cohen, R. J. (1989). Beat to beat variability in cardiovascular variables: noise or music? *Journal of the American College of Cardiology*, *14*(5), 1139–1148. doi: https://doi.org/10.1016/0735-1097(89)90408-7

Arabaci, R., Pehlivan, E., & Gorgulu, R. (2020). Acute effect of different trainings on the variability of the heart rate of young football players. *Physical Education and Sports*, 39(2). doi: https://doi.org/10.17533/udea.efyd.v39n2a02

Aras, D., Akca, F., & Akalan, C. (2014). The effect of 50 m sprint swimming on heart rate variability in 13–14 year-old boys. *Ankara University, Journal of Spormetre Physical Education and Sport Sciences*, 11(1), 13–18. doi: https://doi.org/10.1501/Sporm_0000000233

Aras, D., Karakoc, B., & Koz, M. (2014). Investıgatıon Of The Changes In Hrv In The Immediate 48 Hours following a 1 Hour Running Exercise in Trained Adults, *Ankara University, Journal of Spormetre Physical Education and Sport Sciences*, 12 (1), 35–42. doi: https://doi.org/10.1501/Sporm_0000000251

Ates O., Keskin B., & Cotuk B. (2017). The Effect of Cognitive Strain and Exercise at the Job Place on Heart Rate Variability. *National Journal of Sport Sciences*, 1(2), 55–65

Barlow, M., Woodman, T., Gorgulu, R., & Voyzey, R. (2016). Ironic effects of performance are worse for neurotics. *Psychol. Sport Exerc.* 24, 27–37. doi: https://doi.org/10.1016/j.psychsport.2015.12.005

Baumert, M., Brechtel, L., Lock, J., Hermsdorf, M., Wolff, R., Baier, V., & Voss, A. (2006). Heart rate variability, blood pressure variability, and baroreflex sensitivity in overtrained athletes. *Clin J Sport Med*, 16(5), 412–417. doi: https://doi.org/10.1097/01.jsm.0000244610.34594.07

Beau, G., Prawee, S., Robert, M., Richard, T., & Panton, L. (2015). EPOC Comparison Between Isocaloric Bouts of Steady-State Aerobic, Intermittent Aerobic, and Resistance Training, *Research Quarterly for Exercise and Sport*, 86(2), 190-195. doi: https://doi.org/10.1080/02701367.2014.999190

Camm, A.J., Malik, M., Bigger, J.T., Breithardt, G., Cerutti, S., Cohen, R.J., Coumel, P., Fallen, E.L., Kleiger, R.E., Lombardi, F., Malliani, A., Moss, A.J., Rottman, J.N., Schmidt, G., Schwartz, P.J., & Singer, D.H. (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation*, *93*(5), 1043–1065.

Cancino, J. (2011). Heart Rate Variability: Why Chaos Can Be Healthy? Thinking in Movement: Journal of Exercise and Health Sciences, 9(22), 22-32. Access: https://revistas.ucr.ac.cr/index.php/pem/article/view/389/380

Chen, J. Y., Lee Y. L., Tsai, W., Lee C., Chen P., Li H., Tsai M., Chen H. & Lin J.(2011). Cardiac Autonomic Functions Derived from Short-Term Heart Rate Variability Recordings Associated with Heart Rate Recovery after Treadmill Exercise Test in Young Individuals. *Heart Vessels*, 26(3), 282–288. doi: https://doi.org/10.1007/s00380-010-0048-6

Cohen, J. A power primer. Psychol. Bull. 1992, 112, 155.

Dishman, R. K., Nakamura, Y., Garcia, M. E., Thompson, R. W., Dunn, A. L., & Blair, S. N. (2000). Heart rate variability, trait anxiety, and perceived stress among physically fit men and women. International journal of psychophysiology, 37(2), 121–133. doi: https://doi.org/10.1016/S0167-8760(00)00085-4

Dong, J. G. (2016). The role of heart rate variability in sports physiology. *Experimental and Therapeutic Medicine, 11*(5), 1531–1536. doi: https://doi.org/10.3892/etm.2016.3104

Fairclough, S.H., & Houston, K. (2004). A metabolic measure of mental effort. *Biological psychology*, *66*(2), 177–190. doi: https://doi.org/10.1016/j.biopsycho.2003.10.001

Faul, F., Erdfelder, E., Buchner, A. & Lang, A.-G. (2013) Statistical Power Analyses Using G*Power 3.1: Tests for Correlation and Regression Analyses. Behavior Research Methods, 41, 1149–1160. doi: doi.org/10.3758/BRM.41.4.1149

Fuentes-García J. P., Villafaina, S., Mateo, D.C., Vega, R., Olivares, P.R., & Suárez, V.J.C. (2019). Differences Between High vs. Low Performance Chess Players in Heart Rate Variability During Chess Problems, *Front Psychology, 10*(409). doi: https://doi.org/10.3389/fpsyg.2019.00409

Gaillard, A.W. (2001). Stress, workload, and fatigue as three biobehavioural states: a general overview. In: Hancock PA, Desmond PA (eds) Stress, workload, and fatigue. *Erlbaum, Mahweh*, NJ, pp 623–639

Gaillard, A.W. (1993). Comparing the concepts of mental load and stress. *Ergonomics* 36:991–1006. doi: https://doi.org/10.1080/00140139308967972

Goldberger A. L. (1996). Non-linear dynamics for clinicians: chaos theory, fractals, and complexity at the bedside. *Lancet (London, England)*, *347*(9011), 1312–1314. doi: https://doi.org/10.1016/s0140-6736(96)90948-4

Gorgulu, R., Cooke, A., & Woodman, T. (2019). Anxiety and Ironic Errors of Performance: Task Instruction Matters. *Journal of Sport and Exercise Psychology,* 41, 82-95. doi: https://doi.org/10.1123/jsep.2018-0268

Hashim, I., Townsend, L. K., & Hazell, T. J., (2018). Excess Postexercise Oxygen Consumption and Fat Utilization Following Submaximal Continuous and Supramaximal Interval Running, *Research Quarterly for Exercise and Sport*, 89(4), 450-456. doi: https://doi.org/10.1080/02701367.2018.1513633

Herculano-Houzel, S. (2011). Scaling of brain metabolism with a fixed energy budget per neuron: implications for neuronal activity, plasticity and evolution. *PLoS One*, 6:e17514. doi: https://doi.org/10.1371/journal.pone.0017514

Hiilloskorpi, K., Pasanen, E., Fogelholm. G., Laukkanen, M., & Mänttäri T. (2003). Use of heart rate to predict energy expenditure from low to high activity levels. *Int J Sports Med*, 24(5), 332-6. doi: https://doi.org/10.1055/s-2003-40701

Hills, A. P., Mokhtar, N., & Byrne, N. M. (2014). Assessment of physical activity and energy expenditure: an overview of objective measures. *Frontiers in nutrition*, *1*, 5. doi: https://doi.org/10.3389/fnut.2014.00005

Hottenrott, K., Hoos, O., & Esperer., D. (2006). Heart rate variability and physical exercise. Current status. Herz 31(6), 544–552. doi: https://doi.org/10.1007/s00059-006-2855-1

Hunt, K., & Saengsuwan, J. (2018). Changes in heart rate variability with respect to exercise intensity and time during treadmill running. *BioMedical Engineering OnLine*, 17. doi: https://doi.org/10.1186/s12938-018-0561-x

Hunter, G. R., Bickel, C. S., Fisher, G., Neumeier, W. H., & McCarthy, J. P. (2013). Combined aerobic and strength training and energy expenditure in older women. *Medicine and science in sports and exercise*, *45*(7), 1386–1393. doi: https://doi.org/10.1249/MSS.0b013e3182860099

Hunter, G. R., Weinsier, R. L., Zuckerman, P. A., & Darnell, B. E. (2004). Aerobic fitness, physiologic difficulty and physical activity in Black and White women. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity*, *28*(9), 1111–1117. doi: https://doi.org/10.1038/sj.ijo.0802724

Kaikkonen, P., Rusko, H., & Martınmakı, K. (2008). Post Exercise Heart Rate Variability of Endurance Athletes after Different High-Intensity Exercise Interventions. *Scandinavian Journal of Medicine & Science in Sports,* 18(4), 511–519. doi: https://doi.org/10.1111/j.1600-0838.2007.00728.x

Lam, Y. Y., & Ravussin, E. (2016). Analysis of energy metabolism in humans: A review of methodologies. *Molecular metabolism*, *5*(11), 1057–1071. doi: https://doi.org/10.1016/j.molmet.2016.09.005

Lautenbach, F., Loborde, S., Peter, P., Angelosi, A., & Raab M. (2016). Attentional distraction by negative sports words in athletes under low- and high-pressure conditions: Evidence from the sport emotional Stroop task. *Sport, Exercise Perormance Psychology,* 5(4): 296–307. doi: https://doi.org/10.1037/spy0000073

Luque-Casado, A., Zabala, M., Morales, E., Mateo-March, M., & Sanabria, D. (2013). Cognitive Performance and Heart Rate Variability: The influence of fitness level, *PLoS One*. 8(2). doi: https://doi.org/10.1371/journal.pone.0056935

Maughan, R. J., Fallah, J., & Coyle, F. (2010). The effects of fasting on metabolism and performance. *Br J Sports Med,* 44(7), 490–494. doi: https://doi.org/10.1136/bjsm.2010.072181

Miu, A. C., Heilman, R. M., & Miclea, M. (2009). Reduced heart rate variability and vagal tone in anxiety: Trait versus state, and the effects of autogenic training. *Autonomic Neuroscience-Basic, 145*(1–2), 99–103.

Mukherjee, S., Yadav, R., Yung, I., Zajdel, D.P., & Oken, B. S. (2011). Sensitivity to mental effort and test-retest reliability of heart rate variability measures in healthy seniors. *Clin. Neurophysiol.* 122(10), 2059–2066. doi: https://doi.org/10.1016/j.clinph.2011.02.032

Murray, N. P., & Raedeke, T. D. (2008). Heart rate variability as an indicator of pre-competitive arousal. *International Journal of Sport Psychology*, 39, 346–355.

Rao, J., Oz, G., & Seaquist, E. R. (2006). Regulation of cerebral glucose metabolism. *Minerva endocrinologica*, *31*(2), 149–158.

Shaffer, F., McCraty, R., & Zerr, C.L. (2014). A healthy heart is not a metronome: An integrative review of the heart's anatomy and heart rate variability. *Front. Psychol*. 5:1040. doi: https://doi.org/10.3389/fpsyg.2014.01040

Sloan P. (1994). Effects of mental stress throughout the day on cardiac autonomic control. *Biol Psychol,* 37, 89–99. doi: https://doi.org/10.1016/0301-0511(94)90024-8

Tarvainen, M.P., Niskanen, J.P., Lipponen, J.A., Ranta-aho, P.O., & Karjalainen, P.A. (2014). Kubios HRV-Heart rate variability analysis software. Computer Methods and Programs in Biomedicine. 113, 210–220. doi: https://doi.org/10.1016/j.cmpb.2013.07.024

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience and Behavioural Reviews, 36*(2), 747–756. doi: https://doi.org/10.1016/j.neubiorev.2011.11.009

The grandmaster diet: How to lose weight while barely moving. (2013, 13, September). Access: https://www.espn.com/espn/story/_/id/27593253/why-grandmaster magnus-carlsen-fabiano-caruana-lose-weight-playing-chess

Troubat, N., Fargeas-Gluck, M., Tulppo, M., & Dugue, B. (2008). The Stress Of Chess Players As A Model To Study The Effects Of Psychological Stimuli On Physiological Responses: An Example of Substrate Oxidation and Heart Rate Variability in Man. *European journal of applied physiology*, 105(3), 343-9. doi: https://doi.org/10.1007/s00421-008-0908-2

Uysal, F., & Tokmakci, M. (2017). Evaluatıon Of Stress Parameters Based On Heart Rate Varıabılıty Measurements. *Istanbul University – Journal of Electrical & Electronics Engineering*, 17(1).

Villafaina, S., Collado-Mateo, D., Cano-Plasencia, R., Gusi, N., & Fuentes, J. P. (2019). Electroencephalographic response of chess players in decision-making processes under time pressure. *Physiology & behavior*, *198*, 140–143. doi: https://doi.org/10.1016/j.physbeh.2018.10.017

Westerterp K. R. (2018). Exercise, energy balance and body composition. *European journal of clinical nutrition*, *72*(9), 1246–1250. doi: https://doi.org/10.1038/s41430-018-0180-4

Woodman, T., & Hardy, L. (2003). The relative impact of cognitive anxiety and self-confidence upon sport performance: A meta-analysis. *Journal of sports sciences.* 21. 443–57. doi: https://doi.org/10.1080/0264041031000101809

Received on November 08, 2021
Accepted on March 01, 2022