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The Physiological and Cardiologic Effects of Long Video Gaming Sessions in Adult Males



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ABSTRACT

The effect of long gaming sessions on energy intake, caffeine intake, blood pressure, heart rate, heart rate variability, and biochemical cardiac injury markers is unknown. The objective of this exploratory study was to investigate the changes in healthy male adults during two consecutive 18-hour sedentary video gaming sessions. Nine participants were enrolled in the study. Energy intake was noted in food diaries. Heart rate variability was monitored continuously; blood pressure and cardiac injury markers were measured every three to six hours. During the 42-hour study, the participants had an energy and caffeine intake of 8004.9 kcal and 1354.4 mg, respectively. The participants had a significant decrease in energy intake in the second session ($p = 0.01$). A strong, negative correlation was found between body mass index and total energy intake ($R = -0.84$, $p = 0.005$) and waist circumference and total energy intake ($R = -0.70$, $p = 0.036$) in the first session. No nightly dip in blood pressure or heart rate was observed. Based on this study, long-term adverse effects of gaming cannot be ruled out. The non-dip of HR and BP suggests that long gaming sessions could be detrimental to cardiovascular health long term.

Introduction

Gaming has become a favorite pastime among children, adolescents, and adults. Competitive gaming (e-sport) is gaining popularity as a spectator sport, collegiate sport, and professional competition [1]. A recent review of the physiological and biochemical effects of gaming found that no studies simulated real-life gaming behavior, i. e., gaming for long hours or even days [2]. Additionally,

the authors found that there were no studies of cardiac injury markers. Therefore, this pilot study aimed to explore changes in the physiological parameters and cardiac injury markers during long sedentary video gaming (gaming) sessions and the corresponding eating and drinking behavior.

Among teenage boys and girls in the US, 99 and 94 %, respectively, play video games [3]. In addition, it has been reported that

children spend as much as 7 to 11 hours on weekdays engaged with screen-based after-school activities [4].

Studies have shown that sedentary gaming increases energy expenditure (EE) compared to other seated activities [5, 6], however, not equivalent to that of physical activity or active gaming [7, 8]. Energy intake (EI) has been shown to increase in gamers who played seated video games [5, 9], even as much as in active video games [7, 10]. Additionally, gaming has been linked to the overconsumption of sugar-rich soft drinks in children and youths [11]. In children, it has been proposed that a diet "high in calories but low in nutrients" is an indicator of addictive behavior [12]. The effect of gaming on EI during and after long sedentary sessions is unknown [13].

Most intervention studies have primarily used short gaming sessions of five to 15 minutes [6, 14, 15] to test the effects of gaming, while the most prolonged gaming sessions were close to four hours of video game play [16].

No prior studies have investigated the effects of long gaming sessions on the human heart, combining heart rate variability (HRV) and biochemical markers of cardiac injury. Studies of video games have predominantly used blood pressure (BP), heart rate (HR), and HRV as markers of physical activity and the impact of gaming on the heart and as surrogate markers of the emotional impact of gaming [2, 13, 17, 18]. In addition, HRV has been used as a marker of physiological nervous system stress in the gaming literature [2, 5, 19] and is also used as a predictor of various cardiovascular and psychiatric diseases [20].

Cardiac injury markers (troponin T (TnT), creatine kinase MB (CK-MB), and aspartate transaminase (AST)) have not yet been explored in the gaming literature.

Thus, our knowledge of the effect of the behavior undertaken by millions of children, adolescents, and adults is limited [2].

Methods

The study protocol was approved by The North Denmark Region Committee on Health Research Ethics. The participants gave their written informed consent in the weeks before the study. On the day of the study, each of the participants reaffirmed their consent in writing.

Much input was received during the study protocol design from colleagues, people in the gaming community, and the participants.

Protocol

The original idea of this pilot study was to let participants play video games for as long as they could, let them sleep, and then conduct another gaming session until exhaustion while measuring their physiological and biochemical responses.

On the day of the trial, the participants reported to the test site no later than 4 PM for baseline measurements. Hard physical labor, alcohol, and fast food can affect various biochemical parameters [21–23]. Therefore, the participants were instructed to abstain from hard physical labor, heavy resistance training, strenuous cardiovascular exercise, and alcohol consumption and to limit the consumption of sweets and fast food for seven days before the trial.

Participants were instructed to abstain from food intake from noon on the day of the study and limit the intake of beverages to water. At baseline, the participants completed biochemical and

physiological sampling, including anthropometric measurements, weighing, BP, blood sampling, urine and saliva sampling, and installation of Holter ECG monitors. In addition, the participants completed a questionnaire detailing gaming habits, education, employment, medicine, over-the-counter supplements, tobacco history, and alcohol use.

The first 18-hour session started Friday at 6 PM and ran until Saturday at noon. The second session started at 6 PM Saturday and concluded at noon Sunday. During the 36 hours of gaming, participants had unlimited access to a snack and beverage bar and were served dinner on Friday and Saturday nights. The design simulated an ordinary local area network (LAN) party.

The participants had blood sampled every six hours.

Participants

An announcement of the study with a call for participants was posted on several Danish gaming-related message boards, through word-of-mouth with the local E-sports instructors, and a national gaming organization.

As this was a pilot study, a sample size estimation was not possible. Per protocol, the goal was to recruit six participants and have two additional "backup" participants. During the recruitment process, participants signed up and withdrew from the study in groups. A total of four groups were recruited, but two groups withdrew from the study after a single member of each group withdrew owing to personal reasons. This complicated the enrollment process. Finally, two groups were successfully recruited with a total of nine participants, all completing the trial.

Inclusion criteria were healthy, male adults over 18 years old. Exclusion criteria were baseline hemoglobin below the reference interval (8.3 mmol/L), BP > 150/95 mmHg, hemoglobin A1c (IFCC) > 44 mmol/mol, or known chronic disease.

Food, snacks, and beverages (food diaries)

Before the start, the participants were familiarized with the food diary. The participants kept their food diary, weighing and noting all intake of food and drink from the snack bar immediately after acquiring it. Food diaries were kept in six-hour intervals concurring with blood sampling. Each of the food diaries was indexed with the participants' names, color codes, and correct time intervals. They were located so that the participants could not leave the snack bar without passing their food diaries.

A warm meal was served twice during periods one and five, respectively (► **Table 1**). Consumption of alcohol and recreational drugs was not allowed during the trial. Calorie and caffeine contents of ingested food and drinks were calculated using manufacturer-provided information when possible and USDA FoodData Central estimations [24] when manufacturer information was not available (e. g., pizza, burgers, and coffee).

Blood pressure and heart rate variability

BP was measured in triplicate after a few minutes of rest every three hours using a digital sphygmomanometer (OMRON M6; Mediq Danmark, Brøndby, Denmark) with one minute between every measurement

► **Table 1** Anthropometrics, gaming behavior, and food diary during the study for each gamer.

Gamer	Age	Height (cm)	Weight (kg)	BMI	WC (cm)	DGH (hrs/d)	Total Energy (Kcal)	Total Liquid (kcal)	Total Liquid (ml)	Total Food (kcal)	Total Food (g)	Total Caffeine (mg)
Gamer 1	24.5	180.5	66.5	20.4	77	1.3	7534.4	1163.9	4830	6370.5	1937	1499.5
Gamer 2	26.2	185	84	24.5	91	1.9	7668.0	778.5	8640	6889.4	2250	1038.0
Gamer 3	29.5	189	73.7	20.6	82	3.9	9969.4	1795.5	4980	8173.9	2857	1375.1
Gamer 4	29.3	174.5	81.1	26.6	88	0.9	7485.5	2727.0	9214	4758.5	2072	1625.5
Gamer 5	28.3	185	95.3	27.8	102	5.0	6089.1	714.2	4350	5375.0	1634	669.0
Gamer 6	23.5	186	85.6	24.7	89	3.4	10141.2	4190.5	10820	5950.7	2849	1679.0
Gamer 7	23.9	180	94.1	29.0	99	4.6	8491.2	2026.3	6840	6464.9	2356	1477.0
Gamer 8	23.7	178.5	77.6	24.4	89	5.0	7353.2	1985.0	4180	5368.2	2055	1300.0
Gamer 9	23.3	186.5	87.5	25.2	82.5	4.6	7311.9	1217.8	5770	6094.1	2424	1526.9
Median	24.5	185	84	24.7	89	3.9	7534.4	1795.5	5770	6094.1	2250	1477.0
Mean	25.8	182.8	82.8	24.8	88.8	3.4	8004.9	1844.3	6624.9	6160.6	2270.4	1354.4
	(± 2.6)^a	(± 4.6)^a	(± 9.3)^a	(± 2.9)^a	(± 8.0)^a	3.4	(± 438.4)^b	(± 365.3)^b	(± 801.2)^b	(± 332.9)^b	(± 135.0)^b	(± 106.6)^b

BMI, body mass index; WC, waist circumference; DGH, daily gaming hours.; ^a Standard deviation; ^b Standard error.

HRV data was collected using a Holter monitor (Lifecard CF; Del Mar Reynolds Medical, Hertford, UK). The monitor was attached and tested before baseline blood samples were collected.

The raw data analysis was conducted using the Pathfinder Digital 700 (Del Mar Reynolds Medical) and HRV tools (Del Mar Reynolds Medical).

The 42-hour recording of the study was broken into six-hour intervals that matched the blood sampling schedule and the gaming/rest schedule. Six parameters were included for the study of HRV: high-frequency bands (HF), low-frequency bands (LF), the ratio of LF-to-HF power (LF/HF), average inter-beat interval (mean RR), the root mean square of successive inter-beat interval differences (RMSSD), and the standard deviation of inter-beat intervals from which artifacts have been removed (SDNN) [25].

Gaming

Participants decided what games to play at their discretion. During the 36 hours of gaming, the participants played more than ten different game titles. The games were played alone, cooperatively in groups of two to five players, and now and then, all nine participants played together.

Statistical analysis

The difference in intake of food amount (g), food energy (kcal), liquid amount (ml), liquid energy (kcal), and caffeine amount (mg) was analyzed between the two 18-hour sessions using Student's paired t-test. Normal distribution was tested by the Shapiro-Wilk test of normality. All the data had a normal distribution. However, since the number of observations was low, a Wilcoxon signed-rank test was also performed. This made no difference from the results compared with the paired t-test, and the results are not shown.

Pearson's R correlation analysis was used to investigate correlations between participants' BMI, waist circumference, and habitual gaming hours as independent variables, with the intake of food and drink (both amount and calories) and caffeine intake. All calculations for correlation analysis were conducted manually in Microsoft Excel 2013 (Microsoft Corp., Redwood, Washington, USA).

Average systolic blood pressure (SBP) and diastolic blood pressure (DBP) (± SE) for each triplicate measurement were calculated using Microsoft Excel. Mean arterial pressure (MAP) was estimated using the formula $MAP = (SBP + 2DPB)/3$. There were six missing data points in the BP data. These data points were adjusted using the last observation carried forward (LOCF) technique.

The statistical analyses of HRV and cardiac injury marker data were conducted in R (R Core Team), using a linear mixed-effects model (lme4 package) [26]. The absolute changes of the HRV and biochemical parameters were investigated using this method. A separate univariate analysis for each change in each parameter was conducted. Time was set as the fixed effect, and participants were the random effect. A subsequent model was introduced, which included an interaction term between time and session.

The analyses and visualizations were conducted in R. Results are presented as mean (± SE) unless otherwise stated.

Results

Anthropometrics, gaming behavior, and food diaries

Four of nine participants had a BMI above 25, whereas the rest had normal BMIs. ► **Table 1** gives an overview of relevant anthropometric measurements, gaming behavior, food, liquid, and caffeine intake. The average total calorie intake from food and liquid was 8004.9 kcal (± 438.4 kcal). ► **Table 2** shows ingestion of food and drinks per 6-hour period. Period 4 was the rest period. No food or drinks were ingested during this time. Researchers found that participants had taken items from the snack bar without noting them correctly in their food diary twice. This was corrected immediately during the study.

Food, drink, and caffeine intake

Participants had the highest intake of food, liquid, and caffeine in intervals 1 and 5, right at the start of the two sessions (► **Table 2**) (► **Fig. 1**). The total number of calories ingested (from food and liquid) was higher in the first 18-hour period than in the second 18-hour period ($p = 0.01$) (► **Fig. 2a**), with the difference in means of 1170.8 kcal. Concordantly, the intake of calories from liquid (kcal) was lower in the second period ($p = 0.003$) with the difference in means of 292.0 kcal (► **Fig. 2b**). There was no significant difference between the amount of liquid consumed (ml) between the two periods ($p = 0.99$), and the difference in means was -2.67 ml (► **Fig. 2c**). The

intake of calories from food decreased significantly in the second period ($p = 0.03$) with a difference in means of 878.8 kcal (► **Fig. 2d**). The weight of food eaten fell significantly ($p = 0.04$), with a difference in means of 268.9 g (► **Fig. 2e**). There was no significant difference between caffeine intake in the first period compared with the second period ($p = 0.16$), the difference in means was 93.2 mg (► **Fig. 2f**).

Food calorie intake in the first gaming period was negatively correlated to BMI and waist circumference ($R = -0.84$, $p = 0.005$; $R = -0.70$, $p = 0.036$, respectively). There were no other statistically significant correlations.

Cardiac data

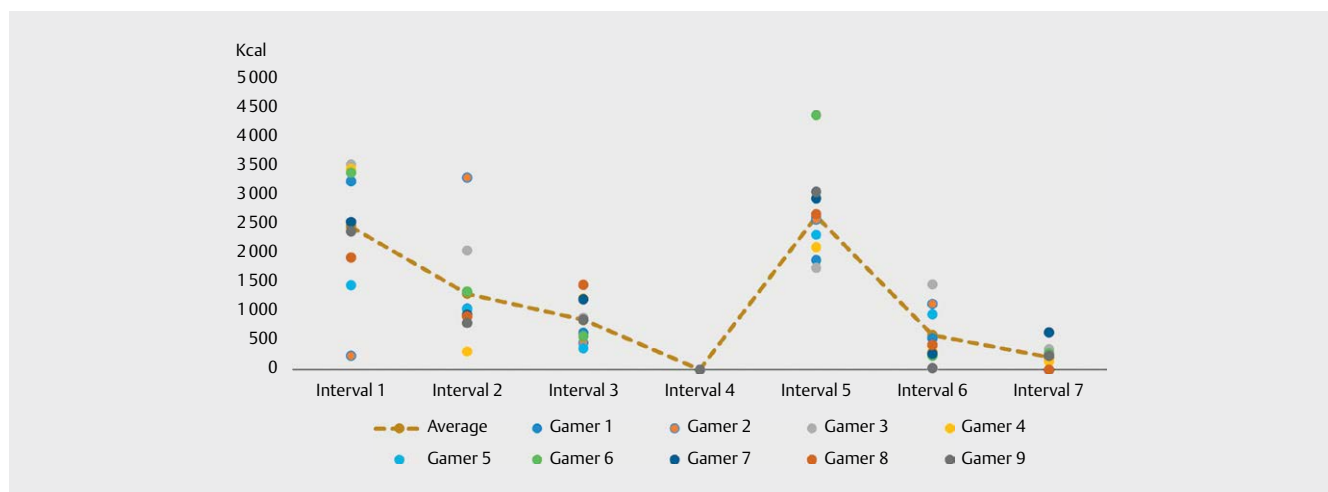
SBP, DBP, and MAP are presented in ► **Fig. 3**. All BP measurements were normal and did not change during the gaming session. Additionally, no statistically significant changes in CK-MB and TnT were observed. However, AST decreased significantly from a baseline of 28.2 U/L. During the first gaming session, AST decreased by 0.6 (± 0.44) U/L per six hours. During the second gaming session, AST decreased by 1.2 (± 0.44) U/L per six hours ($p = 0.02$).

The linear mixed-effects model of the HRV data showed that RMSSD declined significantly over time, -1.54 (± 0.7) from a baseline of 39.9. HF, LF, LF/HF interval, mean RR, and SDNN showed no significant changes. When an interaction term between time and session was introduced, there were no significant changes in the six parameters.

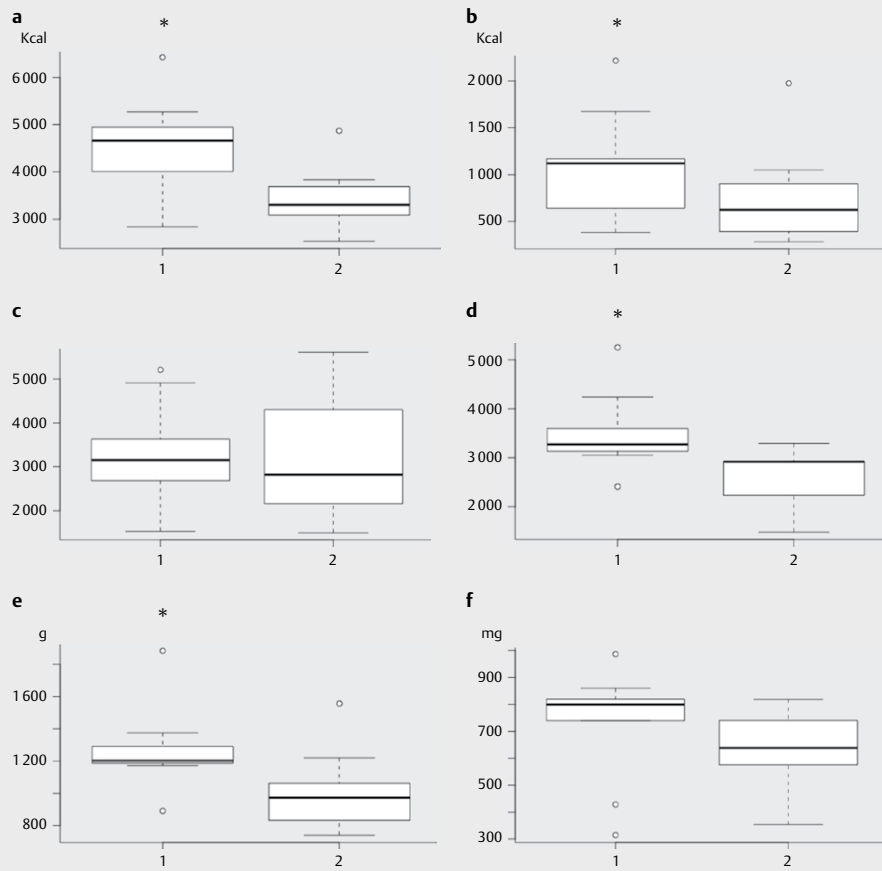
► **Table 2** Overview of the mean intake of food, drink, and caffeine.

	Interval 1 6 PM – Midnight	Interval 2 Midnight – 6 AM	Interval 3 6 AM – Noon	Interval 4 Noon – 6 PM	Interval 5 6 PM – Midnight	Interval 6 Midnight – 6 AM	Interval 7 6 AM – Noon
Liquid (kcal)	615.0 (± 88.9)	281.3 (± 88.0)	171.8 (± 49.9)	0.0	437.5 (± 146.4)	248.4 (± 41.4)	90.2 (± 38.2)
Liquid (ml)	1631.1 (± 203.6)	910.0 (± 174.8)	770.0 (145.2)	0.0	1483.8 (± 291.4)	1191.1 (± 237.8)	638.9 (± 158.9)
Food (kcal)	1828.2 (± 300.0)	1016.0 (± 310.0)	675.5 (± 96.0)	0.0	2176.9 (± 193.8)	343.4 (± 154.5)	120.6 (± 63.9)
Food (g)	689.1 (± 101.7)	305.4 (± 107.6)	275.1 (± 43.0)	0.0	736.3 (± 78.5)	150.9 (± 61.6)	113.6 (± 56.8)
Caffeine (mg)	427.8 (± 45.6)	149.6 (± 13.6)	146.4 (± 25.8)	0.0	328.5 (± 56.9)	202.4 (± 22.5)	99.8 (± 23.2)

Overview of the mean intake of food, drink, and caffeine by 6-hour time interval. Interval 1–3 constitutes the first 18-hour gaming session, Interval 4 was the rest interval, and Interval 5–7 constitutes the second 18-hour gaming session. All data are presented as mean (\pm SE).



► **Fig 1** Intake of total calories for each participant.; Intake of total calories (from both food and liquid) for each participant during each six-hour interval. Meals were served during Interval 1 and 5. Gamer 2 arrived late and thus ate his first full meal during Interval 2.



► **Fig 2** Comparison of intake during gaming sessions.; Boxplot comparison of the first 18-hour gaming period versus the second 18-hour gaming period.; **a:** The total calorie (Kcal) intake.; **b:** Intake of liquid calories (Kcal).; **c:** Intake of liquid amount (mL).; **d:** Intake of food calories (Kcal).; **e:** Intake of food amount (g).; **f:** Intake of caffeine (mg).; * denotes significant difference in a paired Student's t-test ($p < 0.05$).

Discussion

This study is the first of its kind and included a setup that encouraged realistic gaming behavior. In addition, the EI data is unique because it was accumulated over a long period of time.

Design and setting

Gaming is a social behavior [27], and this aspect of gaming should not be disregarded when studies are designed. One participant remarked concerning the gaming room that while it was not designed for gaming, it was more comfortable than most setups at public and private LAN parties. The setup allowed participants to behave in a manner that was congruent with their habitual gaming behavior. While the study did take place at a hospital, it gives a realistic insight into LAN-party and gaming behavior. This study is the first of its kind, using long gaming sessions in a realistic LAN-party setup (Picture 1).

Gaming

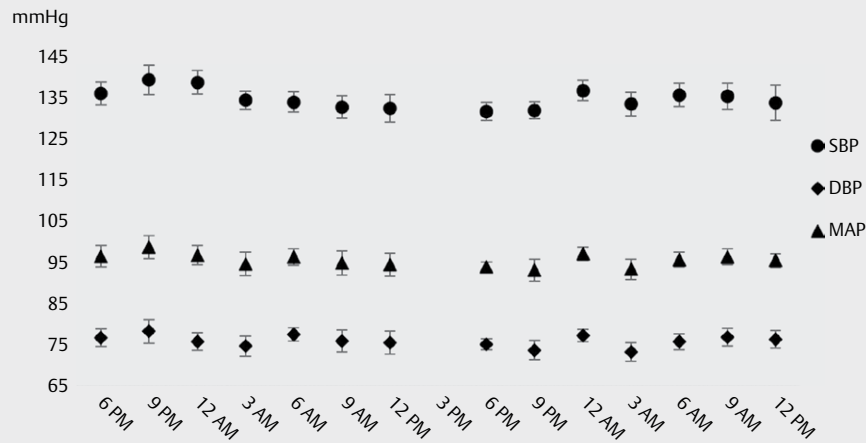
The participants enrolled in this study were experienced gamers and reported playing between one to five hours of video games per day. The participants were not in the habit of undertaking back-to-

back 18-hour gaming sessions, but all the participants had prior LAN-party experience.

The participants played many different games throughout the study. It was previously argued that gaming most likely affects the players according to how the game was played, the requirements of the game, and the stakes of the game [2]. In this study, the participants switched between games and changed the stakes, at their own volition or in collaboration with other participants. As such, this study gives an insight into gaming behavior in general and not specific games or game genres in particular. Studies that investigate e-sports in particular (competitive Counter-Strike: Global Offensive, League of Legends, Fortnite, Dota 2, or similar titles) are scarce in the literature [28].

Food and liquid intake

Previous studies have estimated EI after shorter gaming sessions [5]. This is the first study to collect the data during long gaming sessions. During the study, the participants ingested vastly more calories than what was required in sedentary behavior. The energy required to complete 48 hours of sedentary activity for males in this age group is approximately 4800 kcal [29]. The participants ingested 8004.9 (± 438.4) kcal on average (from food and liquid)



► **Fig 3** Blood pressure during the 42 hours of the study.; Blood pressure was not measured at 3 PM as the participants were resting. SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure.

during the 42 hours of the study. This excessive intake may be necessary to achieve high and consistent performance throughout the long gaming sessions, but this would not explain why the intake of calories fell during the second period. Consequently, overeating may be part of this lifestyle with an excessive supply of snacks. Overall, the number of calories ingested through fluids does not comply with a healthy lifestyle [29]. The data in the food diaries suggest that participants switched from sugary soft drinks to water and coffee (data not shown). At present, we have no explanation for this switch in beverage choice.

The calorie intake from food was significantly lower in the second 18-hour session despite an identical availability of food and drinks. Both sessions included a warm evening meal, and participants had unlimited access to the snack bar. It is possible that the novelty of the snack bar wore off throughout the study or that the participants simply overate during the first hours of the study. Another reason for the decrease in food intake could be exhaustion, though exhaustion has also been correlated with overeating [30].

It was found that higher BMI and bigger waist circumference surprisingly had a strong negative correlation with calorie intake from food in the first 18-hour period. This is not in line with the literature, suggesting that overweight gamers have a larger energy surplus during gaming than normal weight gamers [9]. These correlations may result from a "white coat syndrome" phenomenon, e. g., "unhealthy" participants were aware of their health status and thus consciously limited their EI compared to their habitual gaming behavior. Furthermore, the decrease in calorie intake in the groups during the second 18-hour session was smaller among participants with a BMI > 25 than participants with a BMI < 25 (data not shown). Previous gaming studies have investigated the effect of weight on hunger after gaming [31, 32]. However, this study is, to our knowledge, the first to report a negative correlation between BMI and EI, as well as waist circumference and EI.

Caffeine

The participants had a caffeine intake that equaled approximately double the advised daily maximal intake [29]. Caffeine intake came from liquid, and though liquid calorie intake decreased significantly in the second 18-hour period, a similar decrease in caffeine intake was not registered. The participants changed their sugary soft drinks to coffee as the gaming sessions wore on. Caffeine supplementation is very popular among gamers and e-sports athletes as a performance enhancer, but the positive effect of caffeine on gaming performance has not yet been proven [28].

Cardiac data

The results of our study indicate that gaming per se does not induce unhealthy cardiovascular stress in healthy male adults in the short term.

BP remained steady throughout the study. While this underscores that the physical demand for gaming is limited, it is surprising that there was no dip in BP during the rest period. A dip would be expected during the night but is absent. HR and BP non-dipping during nighttime predict cardiovascular disease [33, 34].

Our results show no clinical difference in HRV during the study, even comparing gaming periods to rest. This lack of variability could indicate cardiovascular stress, and it is reasonable to assume that long, successive gaming sessions that disrupt the circadian rhythm could be detrimental to long-term health [35, 36].

CK-MB and TnT were unaffected. AST decreased significantly throughout the study, however, this is not presumed to be clinically relevant. These results suggest that the overall stress on the body and the heart was limited. Gaming, in general, has been linked to inactivity, obesity, and other cardiovascular risk factors. Gaming does not cause biochemical changes related to cardiac damage, even during extremely long gaming sessions. Gaming can, however, potentially induce health-adverse effects as a part of sedentary behavior.

Conclusion

Based on this study, long-term adverse effects of gaming cannot be ruled out, and further studies are needed.

The non-dip of HR and BP suggests that long gaming sessions could be detrimental to cardiovascular health over the long term. This could be exacerbated by excessive eating patterns. Long gaming sessions may pose a health risk for those who often engage in this behavior.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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