Physiological Changes in Pachinko Players; Beta-endorphin, Catecholamines, Immune System Substances and Heart Rate

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Abstract. Pachinko is a popular form of recreation in Japan. However, in recent years, along with Pachinko’s popularity, “Pachinko dependence” has become topical news. The purpose of this study was to investigate beta-endorphin, catecholamines, immune system responses and heart rate during the playing of Pachinko. The following significant results were observed. (1) Plasma concentration of beta-endorphin increased before playing Pachinko and while in the Pachinko-center (p<0.05). (2) Beta-endorphin and norepinephrine increased when the player began to win (i.e. at “Fever-start”) compared to baseline (p<0.05). (3) Beta-endorphin, norepinephrine and dopamine increased when the winning streak finished (i.e. at “Fever-end”) compared to baseline (p<0.05). (4) Norepinephrine increased past 30 minutes after “Fever-end” compared to baseline (p<0.05). (5) Heart rate increased before “Fever-start” compared to baseline, peaked at “Fever-start” and rapidly decreased to match rates measured at rest. But the increase was observed from 200 seconds after “Fever-start” (p<0.05-0.001). (6) There was a positive correlation between the number of hours subjects played Pachinko in a week and the differences between beta-endorphin levels at “Fever-start” and those at rest (p<0.05). (7) The number of T-cells decreased while the number of NK cells increased at “Fever-start” compared to baseline (p<0.05). These results suggest that intracerebral substances such as beta-endorphin and dopamine are involved in the habit-forming behavior associated with Pachinko.

(Keywords: Pachinko, beta-endorphin, catecholamines, immune system substances, habit-forming)

Introduction

Pachinko is a very popular form of recreation in Japan. It is played in Pachinko parlors or centers which are large halls containing row upon row of brightly colored Pachinko machines. These machines are essentially a combination of pinball and slot machine. Players pay for large number of balls at 4 yen each. As in pinball, play consists in controlling the speed with which each ball is released into a complex arrangement of pins and gates. When a ball enters the start gate this instructs the machine to make a random selection of three numbers or pictures. Similar to what appears in the window of a slot machine, these numbers can be seen spinning on the electronic display screen before coming to rest in a sequence that may or may not signify a win. When a player wins in this way the machine pays out Pachinko balls which can either be fed back into play, or exchanged for prizes, and ultimately for cash. Sometimes the player will win more than 2,000 balls in a single jackpot. For the purposes of our study, the most important point to grasp is that when a player begins to win this can mark the start of a series of consecutive pay-outs which can amount to a considerable sum. This winning streak is known as “Fever”, and comes to an end at a clearly defined moment when the machine stops paying out.

According to “Leisure White Paper ’97” (Leisure Development Center 1997), the population of Pachinko-players in Japan had decreased slightly from 28,100,000 in 1987 to 27,000,000 in 1996. Total sales, however, had risen to 24,0000 billion yen from 11,000 billion yen. An average Pachinko-player, therefore, that was spending 380,000 yen in 1987 increased his spending to 890,000
yen in 1996. These phenomena are thought to reflect the increased perception of Pachinko as a form of gambling. Actually, Pachinko has become a form of high-risk gambling in which prizes or prize money can be obtained, and a player may spend from 15,000 yen to 20,000 yen in one hour's playing. This phenomenon was brought to national attention when some mothers, engrossed in playing Pachinko, left their children in their car on an unusually hot day and the children died. Thus so-called "Pachinko-dependence" became a special news topic. We hypothesized that there may be physiological changes during the playing of Pachinko.

Yamada reported the appearance of FM theta waves in one woman playing Pachinko (Yamada, 1997). Patkai reported that epinephrine secretion increased during an enjoyable game (Patkai, 1971). Furthermore, Yamada et al. reported changes in electroencephalogram readings in subjects playing TV games (Yamada et al., 1991, 1998). But no model for investigating the physiological changes in Pachinko players has yet been put forward.

During various types of exercise, plasma concentrations of beta-endorphin increases (Memmurray et al., 1987; Michael et al., 1987, Sforzo, 1988) and this increase is related to mood changes and "euphoria" (Markoff et al., 1982; Janal et al., 1984, Kraemer, 1990). It has been suggested that so-called experience of "running-high" could be explained by these changes (Appenzeller, 1981; Pargman and Baker, 1980). In addition, the habit of smoking is known to reflect nicotine dependence (DSM IV 1994). As nicotine induces dopamine secretion in the "reward-axis" and motivates smoking behavior, nerve chemical substances such as beta-endorphin modify the affective states or cognitive demands of smokers (Pomerleau 1992; Boyadjiyeva and Sarkar, 1997; Suh et al., 1996).

Our main purpose was to investigate the changes in beta-endorphin and catecholamines in Pachinko players.

Methods

Subjects and measurement

Six adult men (29–44 years old), who were regular Pachinko players, were chosen as subjects. They agreed to cooperate with the experiment, after being informed of the purpose, contents, methods and risks. Beta-endorphin (beta-end), epinephrine (EP), norepinephrine (NE), dopamine (DA) levels, CD3, CD4, CD8, CD16, CD56, and NK cell activity and heart rate were measured. CD3-56 are cell surface antigens (CD: Cluster Determinants). CD 3 is the marker of T cell. CD 4 is the marker of helper T cell. CD 8 is the marker of suppressor T cell and that of killer T cell. CD 16 and CD 56 are the markers of NK cell.

Heart rate

Heart rate was measured in a laboratory for baseline setting. In the Pachinko-center, to measure modification of cardiac frequency (fc), subjects were equipped with a portable fc-recording apparatus (VHM 1-016, Bine Co.with H-R and Interface type 2, Takei Co., Japan), and a continuous recording of the player's fc while in the Pachinko-center was subsequently obtained for analysis with a microcomputer system (PC-9801 VX NEC, Japan).

Blood

Blood was collected while subjects were sitting in a chair in a laboratory (L). The next day subjects were invited to play Pachinko with their own money in a Pachinko-center (business as usual). They were asked to play with so-called "Fever-machines", but they could freely choose their own favorite models. Blood was collected from the subjects before they began playing in the Pachinko-center (P), at Fever-start (FS), at Fever-end (FE) and 30 minutes after Fever-end (A30).

Beta-endorphin and catecholamines

Beta-endorphin and catecholamines levels were analyzed at points L through A30. For beta-endorphin analysis blood was centrifuged immediately to serum and analyzed using the RIA-method. Catecholamine levels were determined using the HPLC-DPA-method.

Immune system substances

Immune system substances in blood were analyzed at points L and FS.

CD, 3, 4, 8, 16 and 56 counts were analyzed using the Ploysotometry-method. NK cell activity was analyzed using the 51-Cr release method (beta-endorphin, catecholamines, CD and NK cell activity were measured by SRL Co., Japan).

Statistical Analysis

To calculate significance, paired t-tests were used. The DA minimum used was 5 pg/ml. For cases measuring below the minimum, DA values were represented as 5 pg/ml, and Wilcoxon signed-ranks tests were used.

Results

Changes in beta-endorphin and catecholamines

The changes in beta-endorphin and catecholamines levels are shown in Table 1. The level of beta-endorphin secreted at P, at FS and at FE increased significantly compared with that at L (p<0.05). DA secreted at FE
increased significantly compared with that secreted at L (p<0.01). The method of analysis did not influence the significance of the results. NE secreted at FS, at FE and at A30 increased significantly compared with that secreted at L (p<0.05). There was no significant change in EP secretion. The correlation between the differences in beta-endorphin levels at FS to those at L and hours spent playing Pachinko in a week were calculated. Consumption hours had been determined by questioning the subjects. Analysis showed that the longer the subjects played Pachinko, the more pronounced the differences in beta-endorphin levels (r=0.887, p<0.05) (Fig. 1).

**Immune system changes**

The changes in CD3-56 and NK cell activity are shown in Table 2. The percentage of CD3 at FS decreased significantly compared with that at L (p<0.05). The number of T cells are thought to have decreased. The percentage of CD16, 56 at FS increased significantly compared with that at L (p<0.05). The number of NK cells are thought to have increased. But NK cell activity did not change significantly.

**Heart rate**

Changes in heart rate are shown in Fig. 2. Heart rate before “Fever-start” was significantly higher than that at L (p<0.05). Heart rate peaked at FS and was significantly higher than that before FS (p<0.05). 100 seconds after peak, heart rate decreased to a significantly low level compared with that at peak (p<0.01). There was no significant difference between heart rate at point L and that at the post-peak decrease. 200 seconds after FS, it was significantly higher than that at post-peak decrease and than that at L (p<0.01).

**Discussion**

**The changes in beta-endorphin, catecholamines and heart rate**

Before playing Pachinko, beta-endorphin secretion increased significantly, catecholamines secretions increased (not significantly) and heart rate was significantly higher than that at L. Beta-endorphin are thought to be related to “mood changes” and “euphoria” (Marcoff et al., 1982; Janal et al., 1984; Grossman and Sutton, 1985; Kraemer, 1990), DA secreted is thought to

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**Table 1** Group data (means ± 1 SE) showing the changes of beta-end, EP, NE, and DA

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>P</th>
<th>FS</th>
<th>FE</th>
<th>A30</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-end</td>
<td>6.8 ± 0.9</td>
<td>9.3 ± 1.3*</td>
<td>10.3 ± 1.8*</td>
<td>9.0 ± 1.1*</td>
<td>7.2 ± 0.9</td>
</tr>
<tr>
<td>EP</td>
<td>77.3 ± 17.7</td>
<td>115.0 ± 28.8</td>
<td>117.3 ± 33.0</td>
<td>101.5 ± 35.8</td>
<td>97.5 ± 36.4</td>
</tr>
<tr>
<td>NE</td>
<td>318.3 ± 50.9</td>
<td>434.0 ± 60.1</td>
<td>462.8 ± 31.6**</td>
<td>453.8 ± 41.4**</td>
<td>432.2 ± 62.6*</td>
</tr>
<tr>
<td>DA</td>
<td>9.0 ± 1.3</td>
<td>11.5 ± 2.7</td>
<td>12.2 ± 3.4</td>
<td>15.0 ± 1.7**</td>
<td>13.5 ± 2.3</td>
</tr>
</tbody>
</table>

*p<0.05, **p<0.01, n=6. L=in laboratory at rest, P=in Pachinko-center at rest, FS=Fever-start, FE=Fever-end, A30=30 minutes after Fever-end at rest. ** in this table shows the result of paired-t-test compared with L. Significant differences were not observed between P-FS, P-PE, P-A30, FS-PE, FS-A30, FE-A30.

**Table 2** Group data (means ± 1 SE) showing the changes in CD3, CD4, CD8, CD16, CD56, and NK cell activities

<table>
<thead>
<tr>
<th></th>
<th>CD3 (%)</th>
<th>CD4 (%)</th>
<th>CD8 (%)</th>
<th>CD16 (%)</th>
<th>CD56 (%)</th>
<th>NK (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>71.3 ± 4.1</td>
<td>45.7 ± 3.0</td>
<td>27.1 ± 2.4</td>
<td>14.3 ± 2.2</td>
<td>15.3 ± 1.4</td>
<td>67.5 ± 3.6</td>
</tr>
<tr>
<td>FS</td>
<td>66.4 ± 2.9*</td>
<td>42.1 ± 3.4</td>
<td>27.2 ± 2.2</td>
<td>19.1 ± 2.2*</td>
<td>18.2 ± 2.1*</td>
<td>58.0 ± 5.0</td>
</tr>
</tbody>
</table>

L=in laboratory, FS=at Fever-start, *p<0.05, n=6.

![Fig. 1](image-url) A scatter graph showing the correlation between consumption hours of Pachinko playing and differences in beta-endorphin secretion from FS to L. R=0.887, p<0.05 y=0.437 x - 0.655.
be involved with "feeling good" and behavior motivation (Schultz et al., 1993; Mirenowicz and Schultz, 1994), and NE secreted has been correlated with heart rate (Kondo et al., 1995). Most subjects report feeling excited on their way to the Pachinko-center. On entering the Pachinko-center they usually want to play right away. Tachi has suggested that psychological changes are related to physiological changes, usually in the brain (Tachi, 1998). Psychological states shortly prior to playing Pachinko may be explained by the increase in beta-endorphin and catecholamines secreted and heart rate change.

At FS, beta-endorphin, EP and NE secreted showed the largest increase. Beta-endorphin and NE secretions increased significantly compared to baseline measurements taken in the laboratory. DA secretion increased (not significantly). In Pachinko magazines the changes in the brain at "Fever-start" have often been described by using the expression "brain juice appears". Such an expression might reflect a behavioral pattern based on neurotransmitter and neuroendocrine function changes such as those caused by beta-endorphin and DA secretion. Heart rate peaked at FS, and decreased to its lowest levels close to baseline measurements 100 seconds later. Beta-endorphin secretion is related to "sedation" (Markoff et al., 1982; Janal et al., 1984; Grossman and Sutton, 1985; Kraemer, 1990), so the decrease in heart rate might be explained by the increase in beta-endorphin. In fact, all subjects reported "feeling relieved" at FS.

At FE, beta-endorphin, NE and DA levels increased significantly compared with those measured sitting in the lab. DA secretion showed the greatest change. It has been suggested that the mesencephalic dopamine neuron involves the motivation of behavior and could be related to the production of emotions (Schultz et al., 1993; Mirenowicz and Schultz, 1994). The significant increase in DA secretion at FE suggests dopamine neuron activity and may reflect the physiological process that motivates people to play Pachinko repeatedly.

Pomerleau has suggested that the changes in neurotransmitter and neuroendocrine secretion after nicotine intake might modify affective states and cognitive demands (Pomerleaur, 1992). The increase in neurotransmitter and neuroendocrine secretion may explain the reason many Pachinko players find themselves motivated to play increasingly frequently.

After 30 minutes rest post-FE, beta-endorphin secretion decreased near the levels measured in the lab. Even if "Pachinko dependence" were caused by beta-endorphin secretion, it may not be so strong. While DA did not change significantly, NE secretion increased significantly and heart rate was significantly higher at A30 compared with that at L. The excitement experienced during "Fever" etc. was not reduced by a 30 minute rest in the Pachinko-center.

**Beta-endorphin and the habit of playing Pachinko**

The number of hours subjects play Pachinko in a week and the differences in beta-endorphin between FS and baseline were positively correlated. This finding indicates that beta-endorphin may be involved in habit-formation in Pachinko players. Thoren et al. proposed the existence of central opioid systems upon which endorphins mainly operate, and connected these systems to the mechanisms of hypertension, drug dependence, depression, and anorexia nervosa. They furthermore suggested the potential therapeutic role of exercise for these disorders (Thoren et al., 1990). If these systems were related to the habit-forming nature of Pachinko, exercise might be beneficial in the management of so-called "Pachinko-dependence". However, cognitive changes regarding Pachinko are assumed to occur in regular players. Cognitive behavior modification techniques are therefore also necessary. Yamawaki and Okamoto summarized previous research regarding the changes of monoamines and neuropeptides in eating disorders and suggested the possibility that some common systems underlie many mental disorders (Yamawaki and Okamoto, 1998). This study suggests that beta-endorphin, NE and dopamine are involved in the habit formation in Pachinko players (Hubner, 1993).

Future studies may focus on monoamines such as serotonin that are strongly related to eating disorders, substance abuse, and compulsive disorders (Weltzin et al., 1994; Kaye, 1992). This line of study would help assess not only the Pachinko-dependence-forming process but also general dependence and habit-forming.
Immune systems

The increase in beta-endorphin induces glucocorticoid secretion from the adrenal cortex which works as an immunosuppressor, and also activates the immune system (Northoff and Berg, 1991; Weicker and Werle, 1991). In this study the number of T cells decreased significantly. NK cell activity decreased (not significantly). But the number of NK cells significantly increased. It is therefore possible that an increase in NK cell activity might be found by the increase of NK cells if longer-term investigations are carried out. We assume that playing Pachinko might work as an “immunosuppressor” and “immunoactivator” for regular Pachinko players. Yamada reported the appearance of FM theta waves in a woman playing Pachinko and pointed out that Pachinko could become a form of meditation and could heal stress (Yamada, 1997). Stress reduction through exercise may also be due to dopamine and endogenous sedatives such as beta-endorphin (Grossman and Sutton, 1985; Pargman and Baker, 1980; Kraemer, 1990). Mimasa et al. reported a positive correlation between beta-endorphin secretion and alpha waves recorded during exercise and conjectured that this physiological activity would induce relaxation (Mimasa et al., 1996). The increase in beta-endorphin and DA secretion in this study suggest that playing Pachinko also has stress reduction effects for regular Pachinko players.

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